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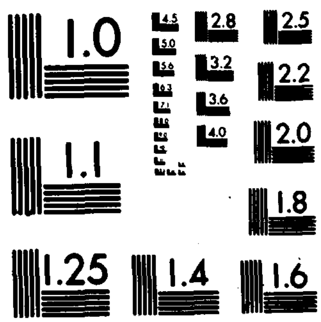

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The first phase of an effort concerning adaptation of Mark IV computer code as an engineering tool to be used in day-by-day design and development work by the members of Air Crew Escape Group (AFWAL/FIER) was carried out. This research effort consisted of the following two parts: (1) modeling the ejection seat/man configuration, namely, representing its surface with a finite number of rectangular elements and inputting the geometry data of the model into the computer in a format acceptable to the Mark IV computer program, (2) computing the six

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A total of five computer models patterned after the models used in wind tunnel test were created. Aerodynamic coefficients were computed for each computer model over an angle-of-attack range of -40 to 60 degrees and a yaw angle range of 0 to 30 degrees. By adjusting various factors which affect the outcome of computation, an attempt was made to identify an optimum computation method.

AFOSR-TR- 80-1254

MINI-GRANT RESEARCH PROGRAM

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FINAL REPORT

COMPUTER CODE FOR THE DETERMINATION OF EJECTION SEAT/MAN AERODYNAMIC PARAMETERS

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COMPUTER CODE FOR THE DETERMINATION OF EJECTION SEAT/MAN AERODYNAMIC PARAMETERS

by

DONALD C. CHIANG

ABSTRACT

The first phase of an effort concerning adaptation of Mark IV computer program [1] as an engineering tool to be used in day-by-day design and development work by the members of Air Crew Escape Group (AFWAL/FIER) was carried out. This research effort consisted of the following two parts: (1) modeling the ejection seat/man configuration, namely, representing its surface with a finite number of rectangular elements and inputting the geometry data of the model into the computer in a format acceptable to the Mark IV computer program, (2) computing the six aerodynamic coefficients using an appropriate pressure law option provided by the Mark IV computer program, and comparing the values predicted by the computer with those obtained from wind tunnel test.

A total of five computer models patterned after the models used in wind tunnel test were created. Aerodynamic coefficients were computed for each model over an angle-of-attack range of -40 to 60 degrees and a yaw angle range of 0 to 30 degrees. By adjusting various factors which affect the outcome of computation, an attempt was made to identify an optimum computation method.

ACKNOWLEDGMENTS

The author would like to express his appreciation to the Air Force Systems Command, Air Force Office of Scientific Research for providing him an opportunity to carry out a research effort in cooperation with the members of Air Crew Escape Group, Crew Escape & Subsystems Branch, Vehicle Equipment Division, Air Force Wright Aeronautical Laboratories.

Special thanks are due to Mr. Lanny A. Jines (FIER) for making all the necessary arrangements enabling access to the AFWAL computer code Gentry Mark IV as maintained by AFWAL/FIGM on the ASD CYBER computer system, Mr. Don Shereda (FIMG) for giving an inital instruction on the usage of computer graphics program and Mark IV computer code and much valuable advice, and David J. Miller (FIER, Wright State University) for rendering assistance on a daily basis to this research effort at the intercom termical as well as at the ASD computer center.

CONTENTS

I. INTRODUCTION:

As a result of a careful survey of computer codes applicable to the determination of ejection seat/man aerodynamic parameters carried out by this author at the Air Force Wright Aeronautical Laboratories during the summer of 1979 under the USAF-SCEEE SUMMER FACULTY RESEARCH PROGRAM sponsored by AFOSR, several computer codes from government sources were found to be applicable in one way or another, but none of them is applicable to the ejection seat/man configuration without further modification and adaptation, nor is any single computer code applicable to the entire performance envelope of the modern high performance air crew escape systems. These computer codes range in scope from relatively simple to highly sophisticated, from an engineering tool to a research oriented program. In his report [2] it was recommended that 1) Mark IV computer program be adapted as an engineering tool to be used in day-by-day design and development work. The primary effort involved in adapting this computer code to the ejection seat/man configuration is modeling and inputting the geometry data into the computer in a format acceptable to the computer program. The secondary effort involves matching various pressure laws with various flow regions surrounding the ejection seat/man configuration by correlating the data obtained from computation with the data obtained from wind tunnel test. 2) USSAERO computer program be adapted as an engineering/research tool to obtain aerodynamic data based on potential flow assumption. 3) A preliminary research program patterned after ATTACK and D3SS computer codes be developed, and 4) a research oriented computer program be developed, incorporating whatever advanced techniques that may be available at the moment for solving full potential flow equations and

Euler's equations.

Recent efforts by Grumman Aerospace Corporation using their High Speed Aerodynamic Prediction Program (HAPP) to predict aerodynamic coefficients of geometries characteristic of an ejection seat/man combination have shown remarkable correlation with basic wind tunnel data for a similar configuration [3]. Furthermore, the in-house capability to conduct investigations of new ejection seat geometrical concepts is of particular interest to the Crew Escape & Subsystems Branch, Vehicle Equipment Division (FIER) and directly relates to expanding the data base knowledge for the computational analysis of escape system performance [4].

A research effort was therefore initiated to adapt Mark IV computer program as an engineering tool to be used in day-by-day design and development work. This research effort was carried out as a follow-on to this author's effort as a Summer Faculty Research Fellow during 1979. This work was accomplished under the Air Force Office of Scientific Research Mini-Grant Contract No. AFOSR-80-0147 during the period from 2 June to 28 August, 1980.

II. OBJECTIVES OF THE RESEARCH EFFORT:

The objectives of this research effort were:

(1) To create model(s) of ejection seat/man configuration, input the geometry data into computer, and verify the correctness of geometry using computer graphics.

(2) To compute the six aerodynamic coefficients for each model using an appropriate pressure law for selected values of angle-of-attack and yaw angle and to compare the results obtained from computation with those obtained from wind tunnel test.

(3) To modify various factors which affect the computational results such as the geometry data, the way in which the data is inputted into computer, the shielding technique, and the pressure law employed in computation in order to improve the computational results and to attempt to identify an optimum method of computation.

III. DEVELOPMENT OF COMPUTER MODELS:

Although it was stated in the Mini-Grant Proposal that "the wind tunnel test data obtained at the AEDC 16T wind tunnel and summarized by B. J. White in the report AFFDL-TR-74-57, 'Aeromechanical Properties of Ejection Seat Escape System' [5] will be used as a standard with which to gage the accuracy of the computed results ...," a newer wind tunnel test data which became available recently in the report AFWAL-TR-80, "Advanced Ejection Seat for High Dynamic Pressure Escape Wind Tunnel Test Report" [6] was used instead for the following two reasons. (1) The newer report contains data obtained from a total of 12 configurations including a 0.5-scale representation of an F-106 ejection seat occupied by a 50th percentile crew member in normal flying clothes and equipment as the basic model (Configuration No. 9, Fig. 1) which is essentially identical to one of three models used in wind tunnel test of the old report. (2) The new data provides a greater variety of configurations to be investigated by this research effort.

A total of five computer models were created. These computer models were patterned after the wind tennel test models designated as configuration Nos. 1, 3, 5, 7, and 9 in Reference 6, (Fig. 1), so that the aerodynamic coefficients obtained from computation may be directly compared with those obtained from wind tunnel test.

Basic seat, or Configuration No. 9, Figs. 2-6, was created first. Configuration No. 9 represents a 0.5-scale representation of an F-106 ejection seat occupied by a 50th percentile crew member in normal flying clothes and equipment. Configuration No. 9 consisted of Crew and Seat. Crew consisted of 5 panels HEAD, NECK, TOSO, ARMS, and LEGS (computer code names) and Seat consisted of 4 panels SEAT, BACK, PADD, and SIDE.

An 18° boom (code name BOOM), Fig. 7, was created next.

Seat with 18° boom, or Configuration No. 5, Figs. 8 & 9, was created by attaching the boom to the basic seat.

An 18° boom and horizontal stabilizer (code name STAB), Fig. 10, was created next. Seat with 18° boom and stabilizer, or Configuration No. 7, Figs. 11 and 12, was created by attaching the 18° boom and horizontal stabilizer to the basic seat.

A blast shield (code name DOME), Fig. 13, was created next. Seat with 18° boom and blast shield, or Configuration No. 3, Figs. 13 and 14, was created by attaching the blast shield to Configuration No. 5, while seat with 18° boom, stabilizer, and blast shield, or Configuration No. 1, Figs. 16 and 17, was created by attaching the blast shield to Configuration No. 7.

The reference area, S, used for data reduction for all configurations was the projected frontal area of the ejection seat including the occupant's protruding extremities. For the half scale wind tunnel model the reference area was 1.86 ft^2. For the half scale computer model the reference area was 251.25 in^2, or 1.74 ft^2.

The reference length, d, was defined as the hydraulic diameter of the model which in turn is defined as the diameter of a circle, d, whose area, S, is equal to the projected area of the seat/man configuration ($\sqrt{4S/\pi}$). The reference length, d, for the half scale wind tunnel model was 18.74 inches and that for the half scale computer model was 17.88 inches.

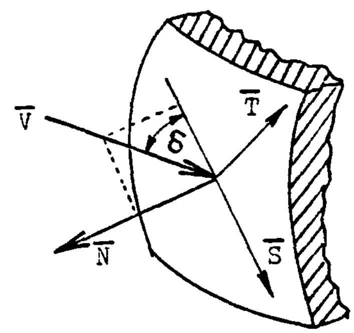
IV. COMPUTATION OF AERODYNAMIC COEFFICIENTS:

Since only the resultant force and moment coefficient of the forces acting on the entire model were desired and no viscous force or the flow field data was desired, Modified Newtonian method was used exclusively in calculating the inviscid pressure forces and Newtonian method was used for the shadow force calculation (i.e., $C_p = 0$).

The modified Newtonian method is the simplest of all force analysis techniques. It is being used widely because of its simplicity, which is also the reason it is employed in this study. The usual form of the modified Newtonian pressure coefficient, K, is defined by the following equation.

$$C_p = K \sin^2(\delta) \qquad (1)$$

where δ is impact angle of the surface element indicated in the drawing at right.



The most general application of Eq. (1) is for blunt bodies at hypersonic speed, because accuracy of this equation becomes better at higher Mach number. Therefore, aerodynamic coefficients for each computer model were computed using a freestream Mach number of 1.5, which was the highest Mach number for which wind tunnel test data were available. Mach number of 1.5 at an altitude of approximately 20,000 ft yields a dynamic pressure of 1,600 psf which marks the approximate upper boundary of the ejection seat/man performance encelope. Four different values for the modified Newtonian pressure coefficient, K = 2.0, 1.8, 1.6, and 1.4, were used in computation.

From the results obtained from preliminary computations, it became clear that shielding of one part of the body by another part of the body had a profound effect on the aerodynamic coefficients, because according to the Newtonian formulation the pressure coefficient is set equal to zero on those portions of the body that are invisible to a distant observer who views the body from the direction of the oncoming freestream. In this study, therefore, the shielding effect was always included in computation.

The following factors which were found to affect the computational results were varied in an attempt to find an optimum method of computation, the method which will produce the best overall results. These factors include:

1) different ways of inputting the geometry data,

2) different ways of grouping surface elements into panels,

3) different combinations of shielding techniques, and

4) different values for the modified Newtonian pressure coefficient, K.

The results obtained from a series of computations are summarized and compared with the results obtained from wind tunnel test.

V. SUMMARY OF RESULTS:

The symbols and notations of the aerodynamic coefficients used in wind tunnel test and those used in Mark IV computer program are slightly different. Fig. 18 illustrates the definition of standardized body axis system and the positive aerodynamic coefficients and angles used in wind tunnel test. Fig. 19 illustrates the input geometry coordinate system used in Mark IV computer program. The following table illustrates the relationship between these two systems of notations.

	Mark IV	Wind tunneld test
Angle of attack	ALPHA	ALPHA (= ALPHA of Mark IV)
Yaw angle	BETA	PSI (= - BETA)
Axial force coefficient	CA	CX (= - CA)
Side force coefficient	CY	CY (= CY)
Normal force coefficient	CN	CZ (= - CN)
Pitching moment	CM	CMM (= CM)
Rolling moment	CLL	CML (= CLL)
Yawing moment	CLN	CMN (= CLN)

It was found that if the sign of all numbers except those of ALPHA and CMM in the wind tunnel test report was reversed, those numbers became directly comparable with those obtained from computation. Therefore, the symbols and notations used in Mark IV computer program were used in this report. Furthermore, since the tabulated coefficients of wind tunnel test report were in the standardized X, Y, and Z body axis system with moment reference center at the seat reference point (SRP, Fig. 18), the center of gravity (CG) location of the computer model was artificially set at SRP so that the computed moment coefficients were also referred to SRP in order to facilitate comparison of the results.

The results of a total of 22 study cases were presented in graphic form in Fig. 20 through Fig. 35. The test case conditions and configurations were as summarized in Table 1. In Table 1, the test cases are arranged in chronological order with only a few exceptions. Computations were made for four of the five computer models. No computation was made for Configuration No. 1 for two reasons: 1) It was the most complicated configuration, and 2) shortage of time. Configuration No. 9, or the basic seat/man configuration, was studied most extensively. The tricks, namely, variation and combination of the factors summarized in page 7, learned from numerous trial runs with Configuration No. 9 were then applied to the computation made for the other configurations, No. 3, No. 5, and No. 7.

It is evident from Fig. 20(a) that shielding effect must be taken into consideration. However, simple shielding, or shielding of one panel by no more than one or two other panels, was found to produce much better results than extensive shielding. (See Case No. 3, Table 1 for an example of extensive shielding.)

Figs. 21, 22, and 23(a) illustrate the results obtained from Configurations No. 7, No. 5, and No. 3 with an application of the rule of simple shielding technique referred to above. Figs. 21 and 22 show clearly that the computed results can predict the overall trend correctly. However, Fig. 23(a) shows that the computed results failed to predict the correct trend. The reson for this failure was attributable to the complexity of the model. For example, there are altogether four layers of panels:

Blast shield, Crew, Seat, and Boom. Therefore, some change in geometry data of Configuration No. 3 must be made in order to improve the results.

A change was made at some later time in Case No. 18 by the creation of Configuration No. 3A. Configuration No. 3A was created by deleting that portion of CREW which is inside the blast shield and then closing the bottom of the blast shield. Fig. 23(b) shows the results obtained from Configuration No. 3A. Clearly, the computed results are showing the correct overall trend comparable in degree of accuracy to those shown in the two previous figures.

Fig. 24(a) shows the results obtained from Configurations No. 9B and No. 9C. Configurations No. 9B and No. 9C were created, respectively, by simply deleting SIDE and SIDE & PADD from Configuration No. 9. The excellent agreement between the computed results and the wind tunnel test results seems to hint at a rule that "too much detail in computer model does not necessarily bring better results."

Configuration No. 9X was created by deleting SIDE from Configuration No. 9 and adding NEGA which represents the overlapping area between CREW and SEAT. This area was treated as a negative area using one of the computational options available. Although the results shown in Fig. 24(b) did not show any marked improvement in the results, this is one of the areas where further study and experimenting need to be carried out.

Fig. 25 (a) and (b) show the results obtained from 2-panel and 9-panel (Configurations No. 9A and No. 9, respectively) geometry representation of the identical geometry. The simple shielding scheme used in 2-panel geometry can be seen to yield somewhat better results than a more complicated shielding scheme of 9-panel geometry.

At this point, a brand-new Configuration No. 9Y was created. Its dimensions were identical to those of Configuration No. 9 except for the absence of the arm-guard which was a part of SIDE and the "thigh" of the new configuration was enlarged to include the leg-guard/hand grip which was a part of SIDE in the old configuration. In addition, the method of geometry data input was different and the most drastic deviation from Configuration No. 9 was the fact that the area designated as NEGA in Configuration No. 9X was not included in Configuration No. 9Y. That is to say that CREW of Configuration No. 9Y does not form a completely closed surface. It is evident from what is shown in Fig. 28(a) that the results obtained from Configuration No. 9Y are, if not better, comparable to those obtained from Configuration No. 9A, Fig. 25(a). This exercise confirmed once more the profound effect the geometry data have on the computational results. Fig. 28(b) shows the results obtained from Configuration No. 9Y for a subsonic Mach number of 0.9 and a modified Newtonian pressure coefficient K = 1.4. The results were surprisingly in good agreement with those of wind tunnel test. Mark IV computer program appears to be applicable even in the subsonic domain. This is another area in which further research needs to be carried out.

Figs. 29-31 and 33-35 show the results obtained from varying the yaw angle BETA while the pitch angle ALPHA was held at zero degree for Configurations No. 9A, No. 7, No. 5, No. 9, No. 9Y and No. 3A, respectively. Although there were different degrees of agreement, in every case studied the general trend was correctly predicted by the computational results.

VI. RECOMMENDATIONS:

This research effort has been a brief exercise in adaptation of Mark IV computer program as an engineering tool for the prediction of aerodynamic parameters of an ejection seat/man configuration. In spite of the relatively simple and crude computer models used, the results obtained from application of Mark IV computer program were found, in general, capable of predicting the overall trend. The degree of accuracy was found to be affected definitely by 1) the model geometry itself, 2) the way geometry data is organized, 3) the shielding scheme which is related to item 2), and 4) the modified Newtonian pressure coefficient, K.

This research effort was able to identify an outline of an optimum method of computation. With further study the optimum method of computation should be able to be brought into sharper focus.

Recommendations:

(1) A more refined computer model be created and studied. However, too elaborate a computer model probably will defeat the original purpose of this effort.

(2) Various geometry data input techniques be tried in conjunction with the shielding schemes.

(3) The problem of overlapping areas requires further study and investigation. The question is how to reduce the number of overlapping layers.

(4) Computation in the subsonic domain needs to be explored.

Finally, this effort is more an "art" than science. However, the art must be guided by scientific feedback in order to achieve the ultimate goal.

ILLUSTRATIONS

ILLUSTRATIONS

TABLES

Table 1. Summary of Test Case Conditions and Configurations (Sheet 1 of 2)

CASE NO.	CONFIG. NO.	CONFIGURATION DESCRIPTION	SHIELDING COMBINATION (1)	ALPHA	BETA	RESULTS AND NOTES (2)
1	9	Figs. 2-6; 9 panels: 1. HEAD, 2. NECK, 3. TOSO, 4. ARMS, 5. LEGS, 6. SEAT, 7. BACK, 8. PADD, 9. SIDE.	None	Variable	0	Fig. 20 (a); K = 1.8; DCCS7XB, 7/14
2	9	See Case No. 1.	6/(1-5); 7/(1-5); 8/(1-3)	Variable	0	Fig. 20 (a); K = 1.8; DCCS70S, 7/16
3	9	See Case No. 1.	1/(2,3,5); 2/(1,3,5); 3/(1,2,5,6); 4/(5,6,9); 5/(6); 6/(3,4,5); 7/(1,2,3,4,5,8,9); 8/(1,2,3,5,6)	Variable	0	Fig. 20 (b); K = 1.8; DCCS7W1, 7/25
4	9A	2 panels: 1. CREW, 2. SEAT.	1/2; 2/1	Variable	0	Fig. 20 (b); K = 1.8; DCCS72J, 7/23
5	7	Figs. 11 & 12; 3 panels: 1. CREW, 2. SEAT, 3. STAB.	2/1; 3/2	Variable	0	Fig. 21; K = 1.4 - 2.0; DCCS71J/1U/18/1Z, 7/30
6	5	Figs. 8 & 9; 3 panels: 1. CREW, 2. SEAT, 3. BOOM.	2/1; 3/2	Variable	0	Fig. 22; K = 1.4 - 2.0; DCCS72J/2N/2Q/2V, 7/30
7	3	Figs. 14 & 15; 4 panels: 1. CREW, 2. SEAT, 3. BOOM, 4. DOME.	1/4 2/1 3/2	Variable	0	Fig. 23 (a); K = 1.6 - 2.0; DCCS73G/3L/3P, 7/31
8	9B	8 panels: 1. HEAD, 2. NECK, 3. TOSO, 4, ARMS, 5. LEGS, 6. SEAT, 7. BACK, 8. PADD.	6/(1-5) 7/(1-5) 8/(1-5)	Variable	0	Fig. 24 (a); K = 1.4 DCCS73C, 7/31
9	9C	7 panels: 1. HEAD, 2. NECK, 3. TOSO, 4. ARMS, 5. LEGS, 6. SEAT, 7. BACK.	6/(1-5) 7/(1-5)	Variable	0	Fig. 24 (a); K = 1.4; DCCS73A, 7/31
10	9X	9 panels: 1. HEAD, 2. NECK, 3. TOSO, 4. ARMS, 5. LEGS, 6. SEAT, 7. BACK, 8. PADD, 9. NEGA.	6/(1-5) 7/(1-5) 8/(1-5)	Variable	0	Fig. 24 (b); K = 1.8; DCCS7Z4, 8/1
11	9X	See Case No. 10.	None	Variable	0	Fig. 24 (b); K = 1.8; DCCS7Z4, 8/2

Table 1. Summary of Test Case Conditions and Configurations (Sheet 2 of 2)

CASE NO.	CONFIG. NO.	CONFIGURATION DESCRIPTION	SHIELDING COMBINATION (1)	ALPHA	BETA	RESULTS AND NOTES (2)
12	9A	See Case No. 4.	2/1	Variable	0	Fig. 25 (a); K = 1.4 - 2.0; DCCS7X1/YL/YK, 8/4
13	9	See Case No. 1.	6/(1-5); 7/(1-5); 8/(1-5)	Variable	0	Fig. 25 (b); K = 1.4 - 2.0; DCCS7Y7/ZE/ZK/ZT, 8/5
14	9Y	Figs. 26 & 27; 2 panels: 1. CREW, 2. SEAT.	2/1	Variable	0	Fig. 28 (a); K = 1.4 - 2.0; DCCS7YH/YC/YU/YV, 8/6
15	9A	See Case No. 4.	2/1	0	Variable	Fig. 29; K = 1.4 - 2.0; DCCS7YO/YY/Y2/Y5, 8/6
16	7	See Case No. 5.	2/1; 3/2	0	Variable	Fig. 30; K = 1.4 - 2.0; DCCS7XF/YN/YP/YR, 8/7
17	5	See Case No. 6.	2/1; 3/2	0	Variable	Fig. 31; K = 1.4 - 2.0; DCCS7XM/X2/X5/YE, 8/7
18	3A	Fig. 32; 4 panels: 1. CREW, 2. SEAT, 3. BOOM, 4. DOME.	1/4; 2/4; 3/2	Variable	0	Fig. 23 (b); K = 1.4 - 2.0 DCCS7EE/EA/DA/D4, 8/11
19	9	See Case No. 1.	6/(1-5); 7/(1-5); 8/(1-5)	0	Variable	Fig. 33; K = 1.4 - 2.0; DCCS7Y5/ZA/ZD/ZC, 8/12
20	9Y	See Case No. 14.	2/1	0	Variable	Fig. 34; K = 1.4 - 2.0; DCCS7ZG/ZI/ZJ/ZK, 8/12
21	9Y	See Case No. 14.	2/1	Variable	0	Fig. 28 (b); K = 1.4; Mach=0.9 DCCS718, 8/13
22	3A	See Case No. 18.	1/4; 2/4; 3/2	0	Variable	Fig. 35; K = 1.4 - 2.0; DCCS72Y, 8/13; DCCS7YB/YX/ZI, 8/14

NOTE: (1) For example, 6/(1-5) means "panel 6 shielded by panels 1 through 5."
(2) Results are shown in graphic form. K represents the modified Newtonian pressure coefficient. The sources of the original computer output data are identified by the computation Jobnumber and date.

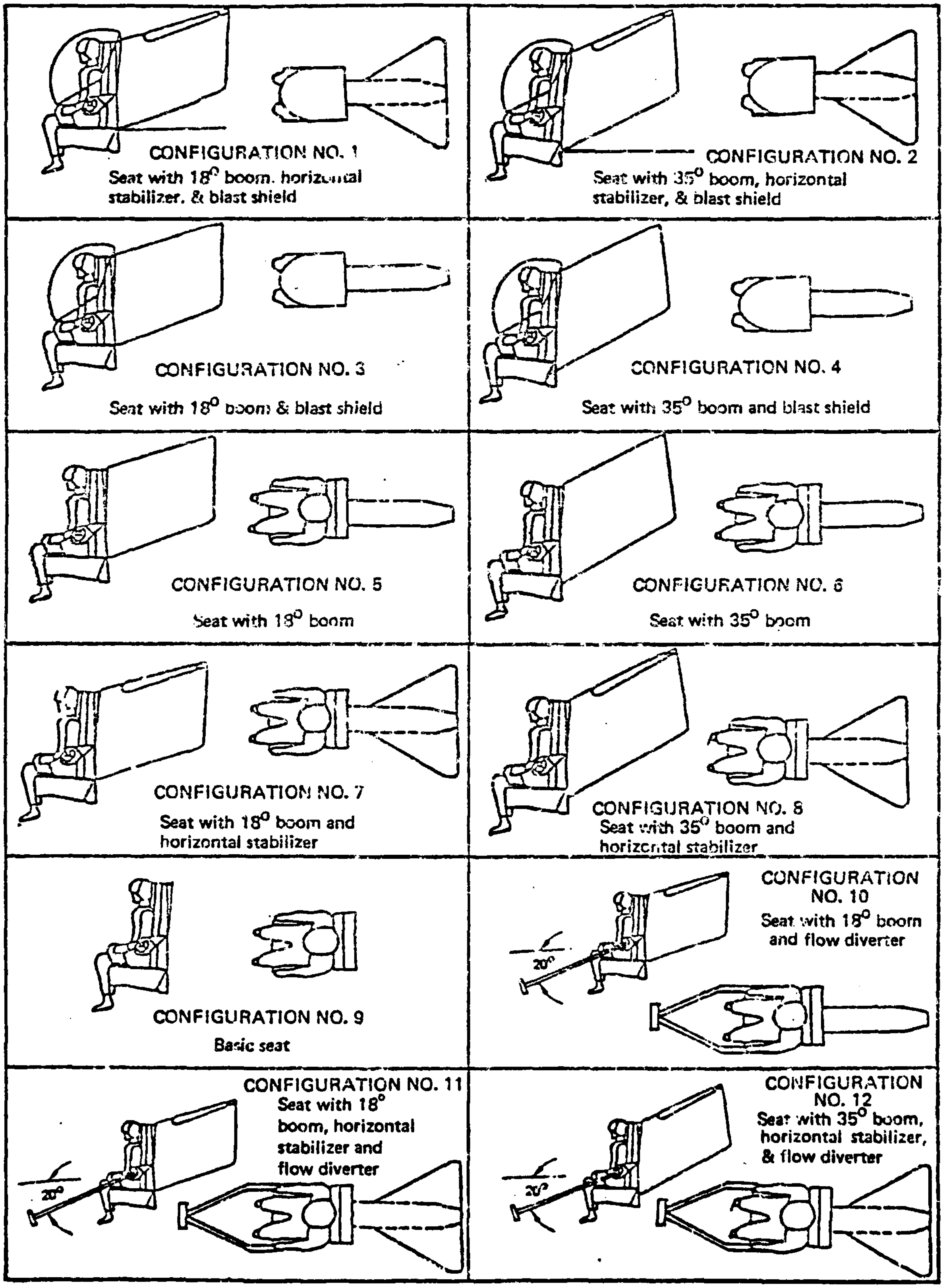


Fig. 1 High Q Ejection Seat Wind Tunnel Test Configurations (Fig. 6 of Ref. 6)

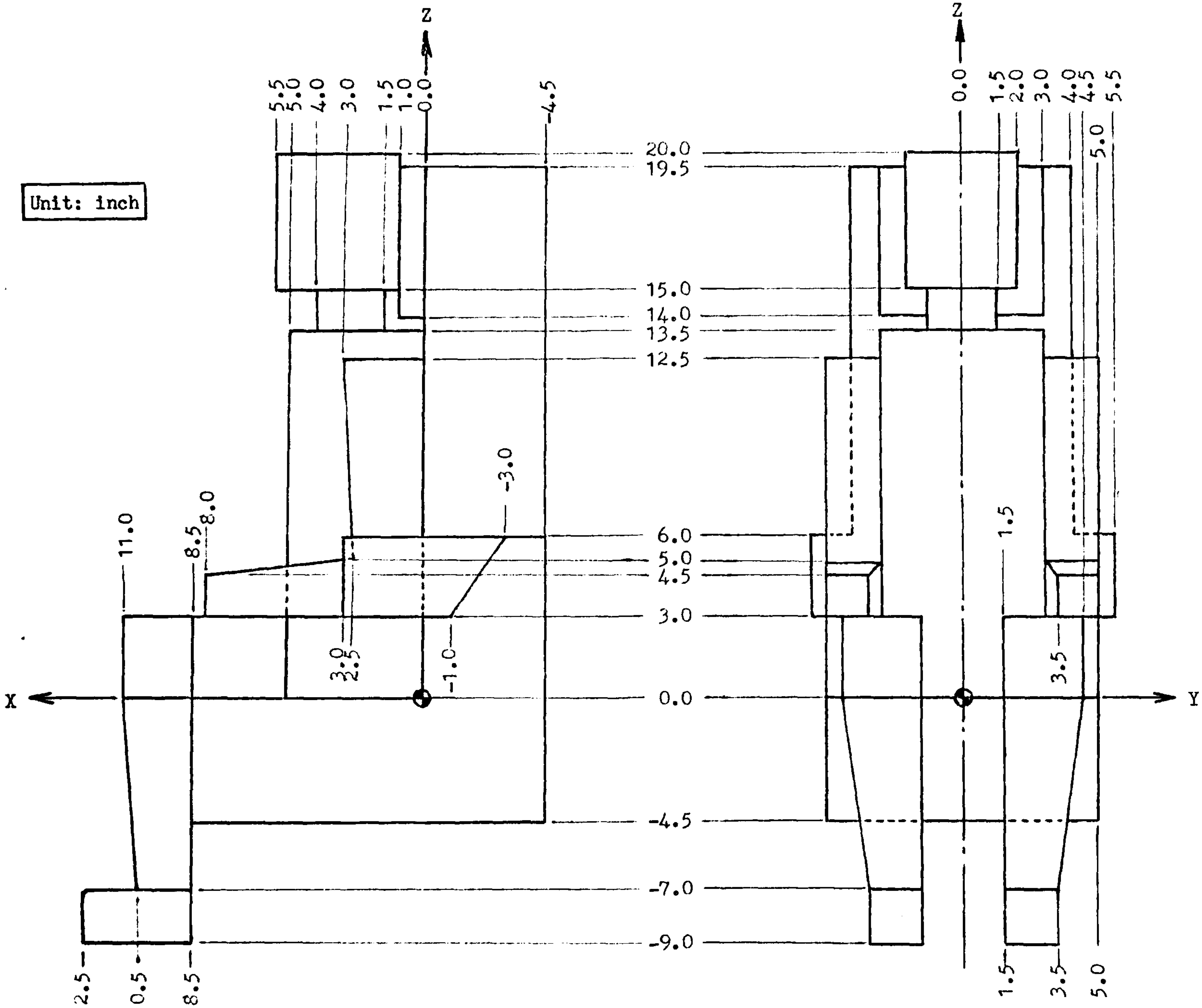


Fig. 2 Computer Model Configuration No. 9 - Model Reference Dimensions

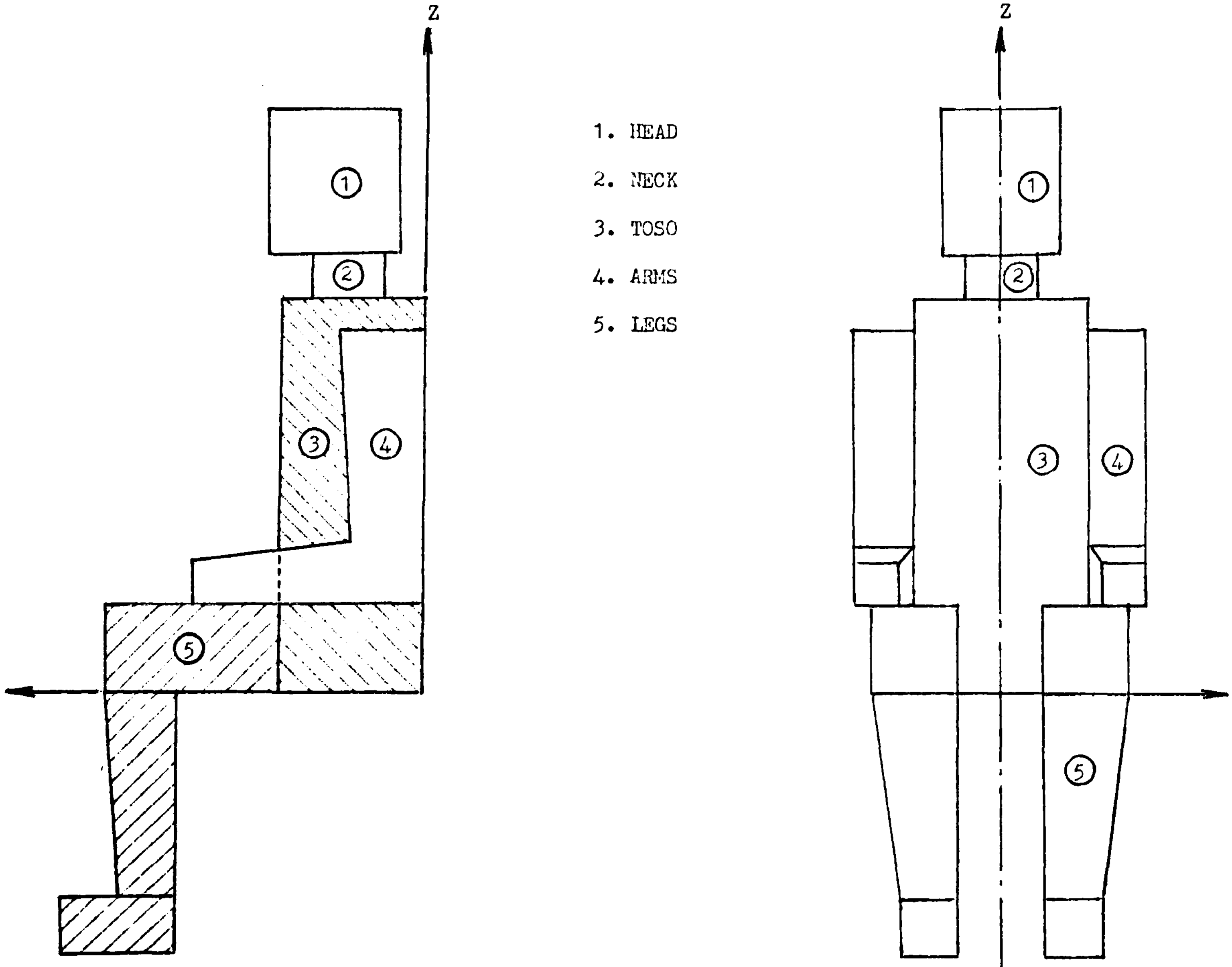


Fig. 3 Computer Model Configuration No. 9 - Names of Panels composing CREW

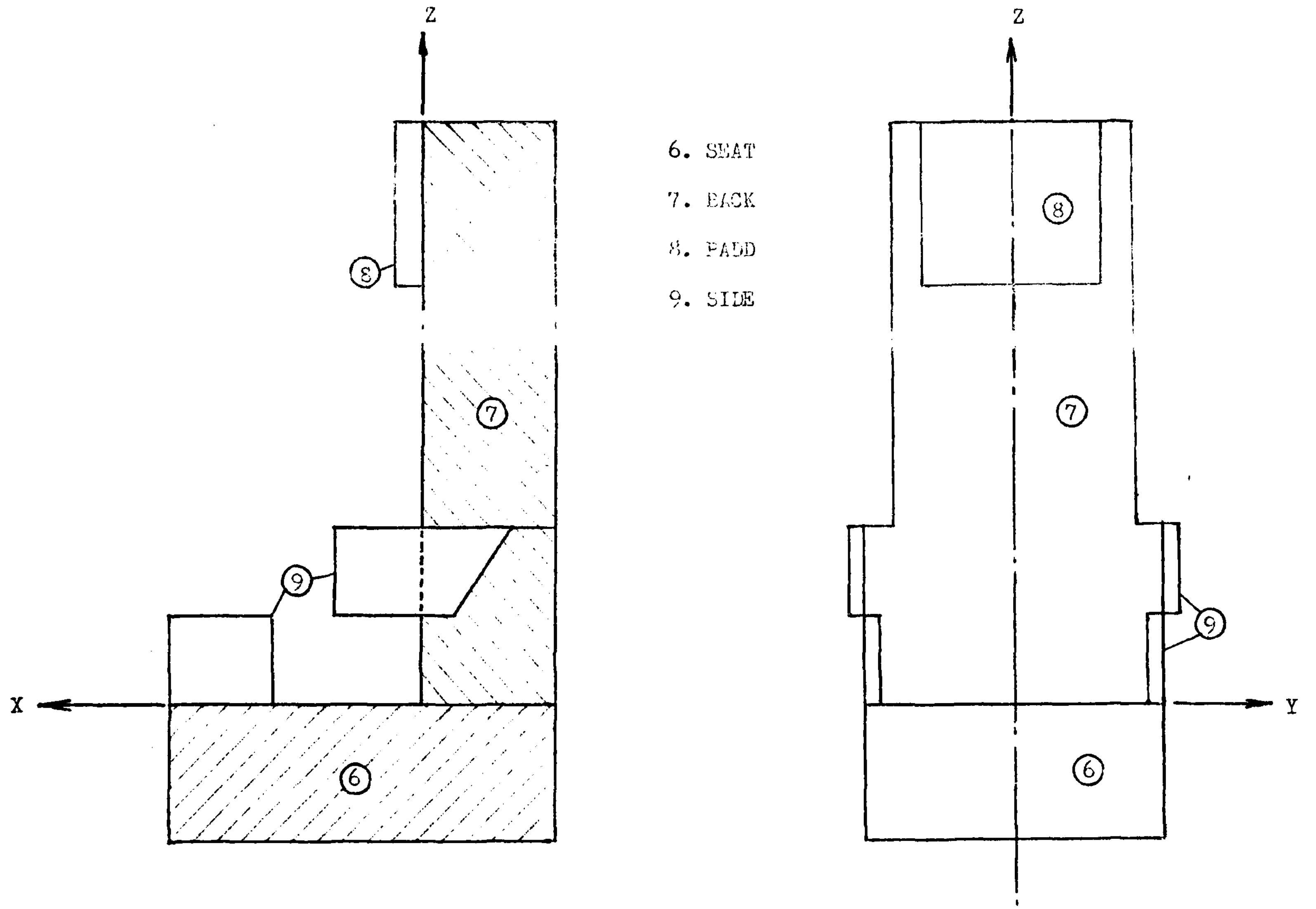


Fig. 4 Computer Model Configuration No. 9 - Names of Panels composing SEAT

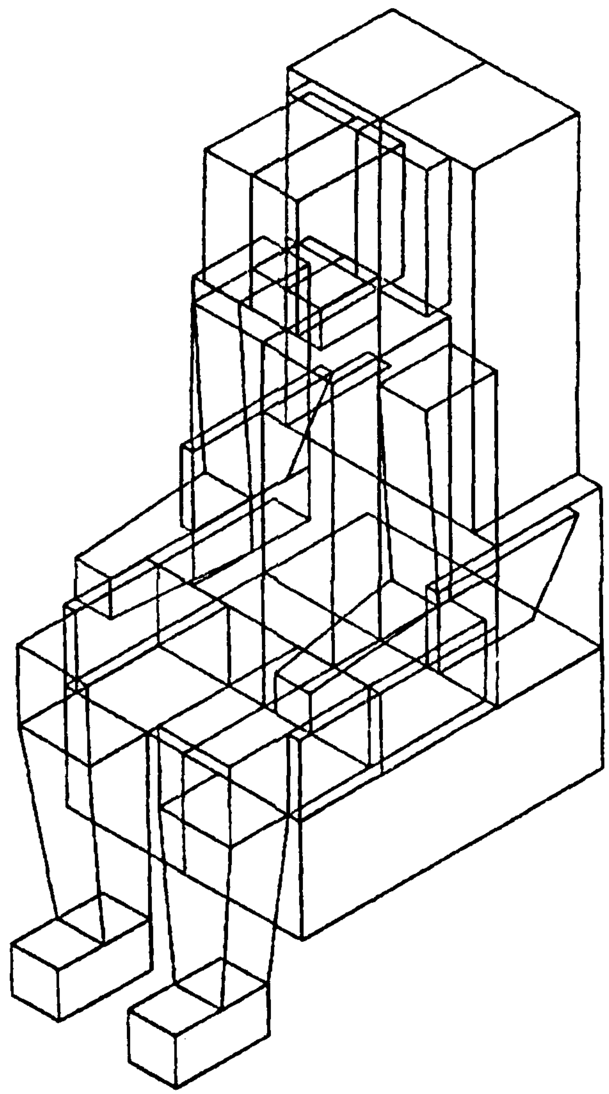


Fig. 5 Computer Model Configuration No. 9 - Picture drawn by Computer Graphics

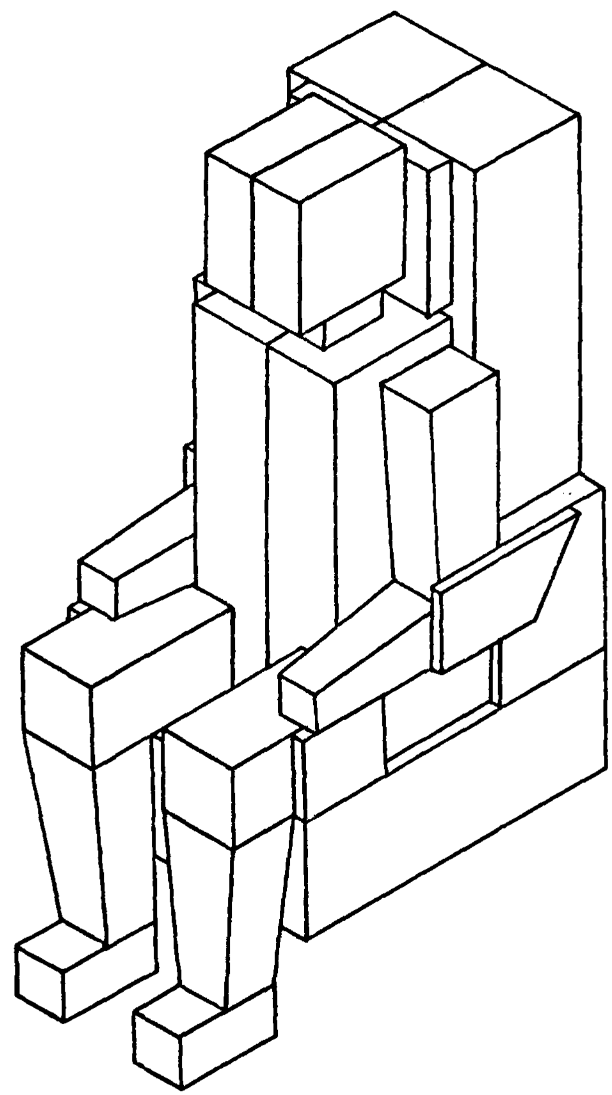


Fig. 6 Computer Model Configuration No. 9 - Perspective View

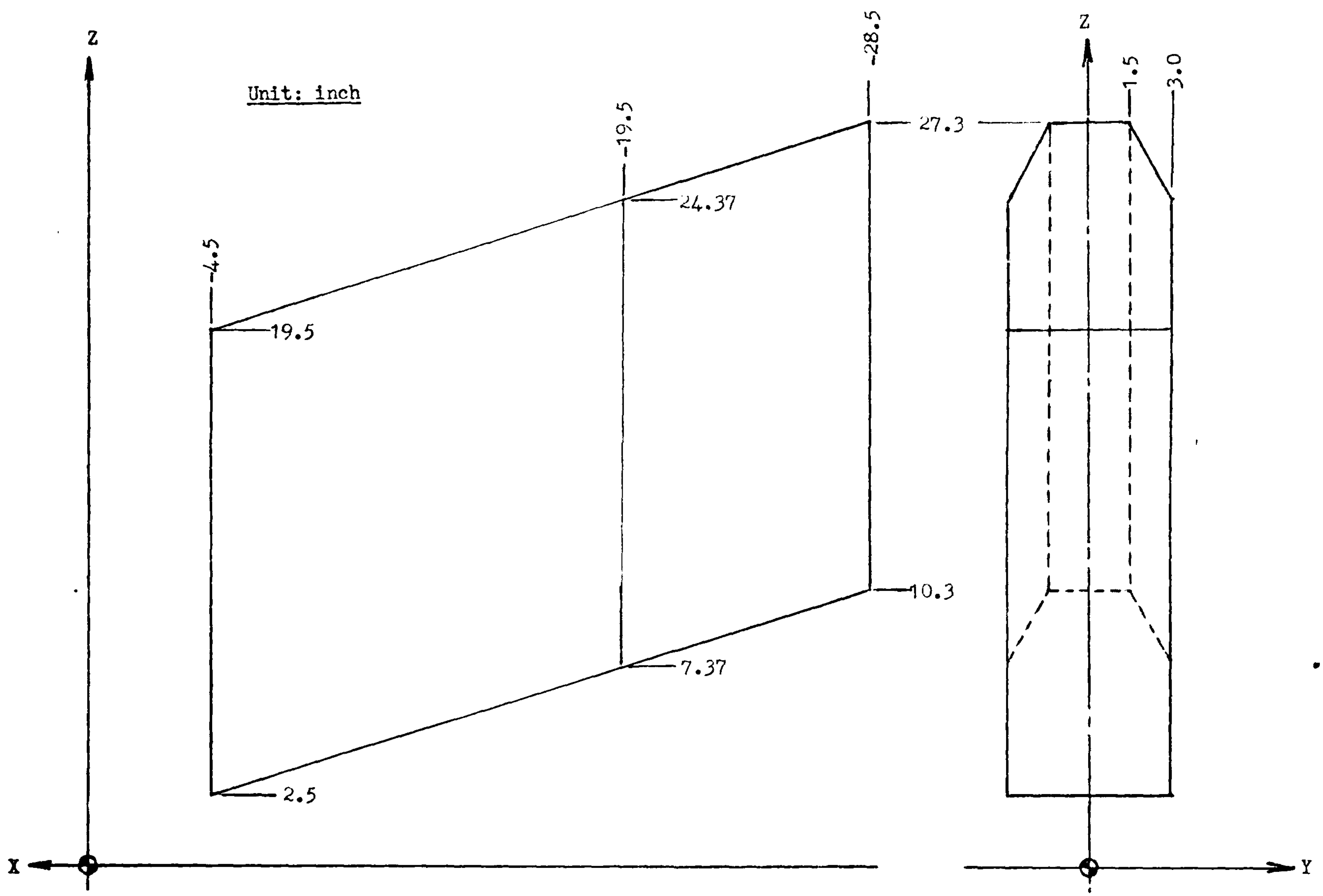


Fig. 7 Computer Model Boom - Model Reference Dimensions

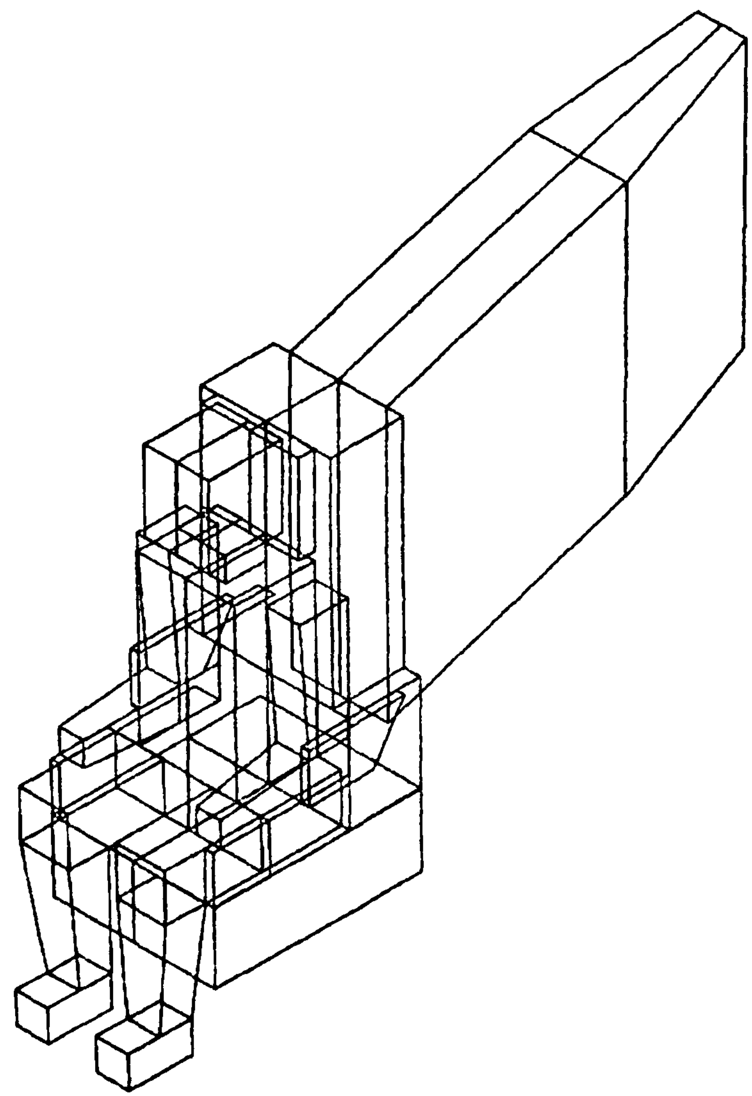


Fig. 8 Computer Model Configuration No. 5 - Picture drawn by Computer Graphics

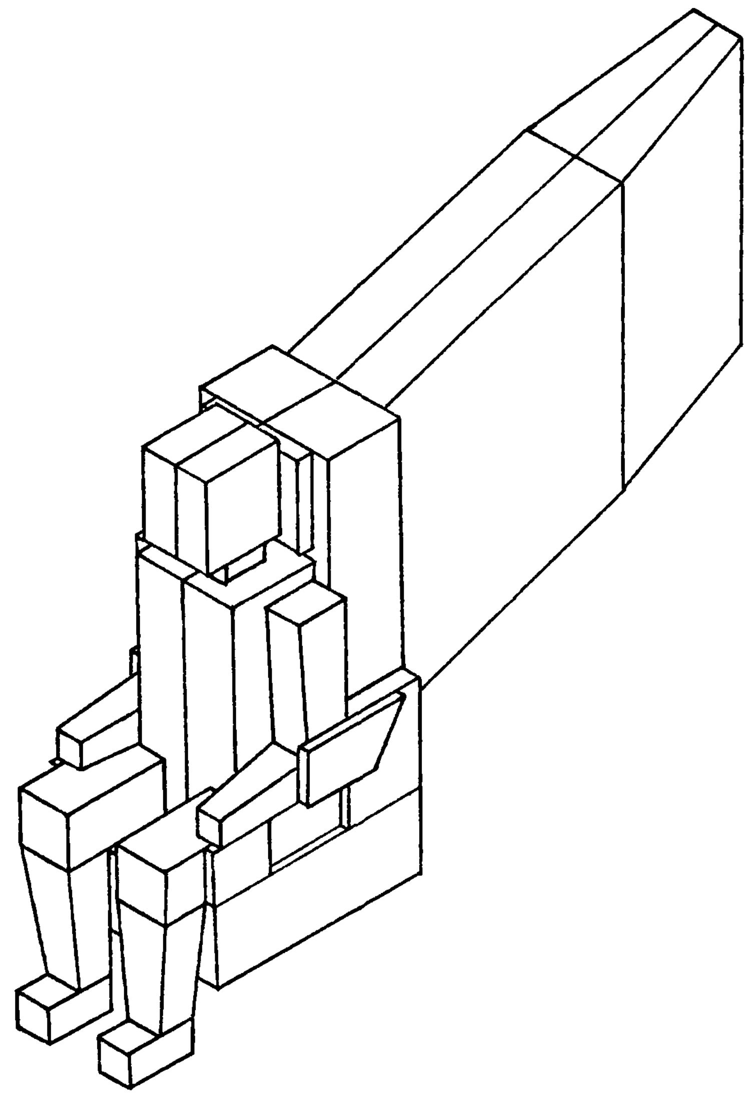


Fig. 9 Computer Model Configuration No. 5 - Perspective view

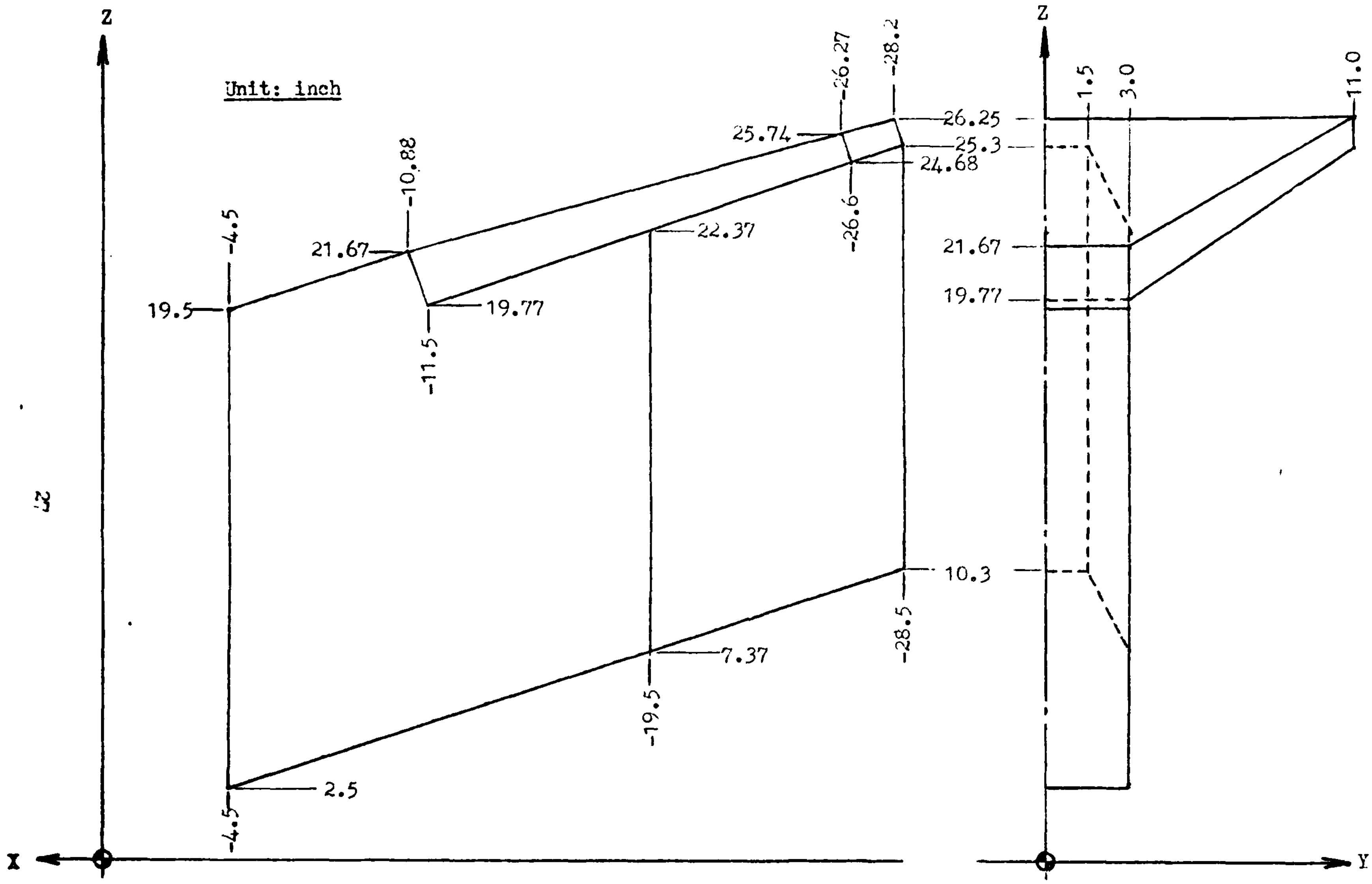


Fig. 10 Computer Model Boom & Stabilizer - Model Reference Dimensions

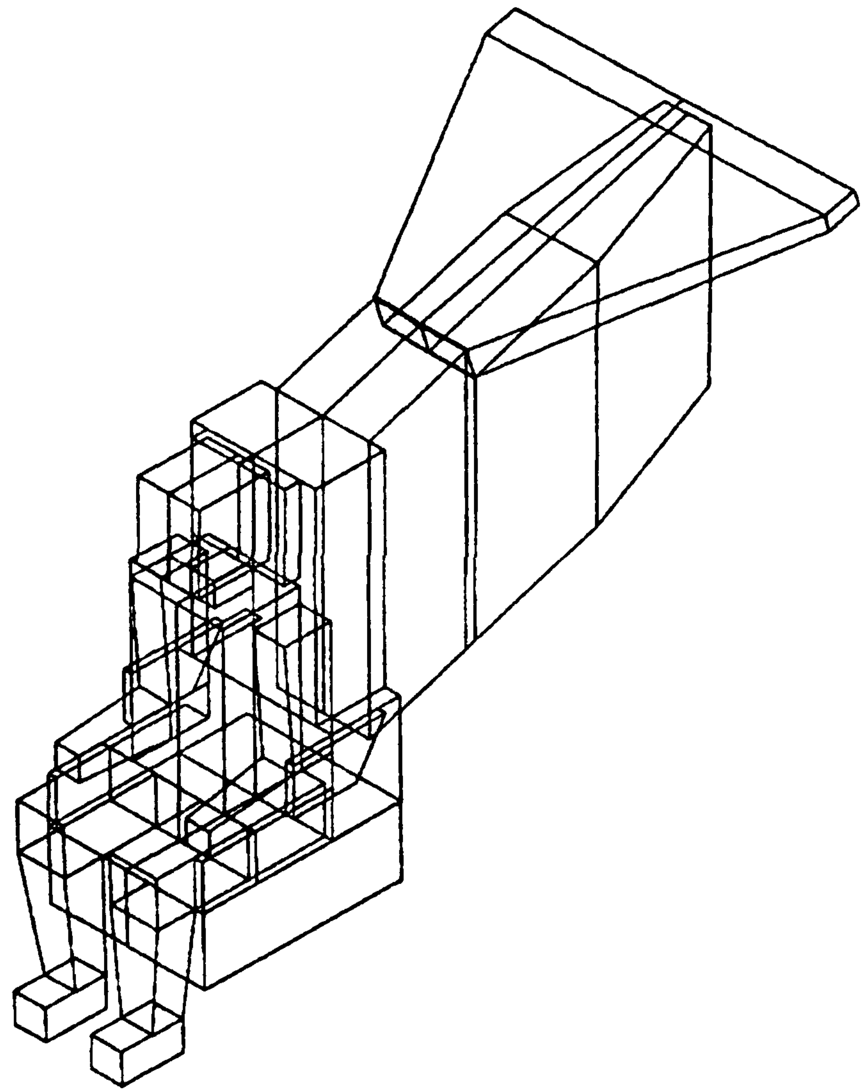


Fig. 11 Computer Model Configuration No. 7 - Picture drawn by Computer Graphics

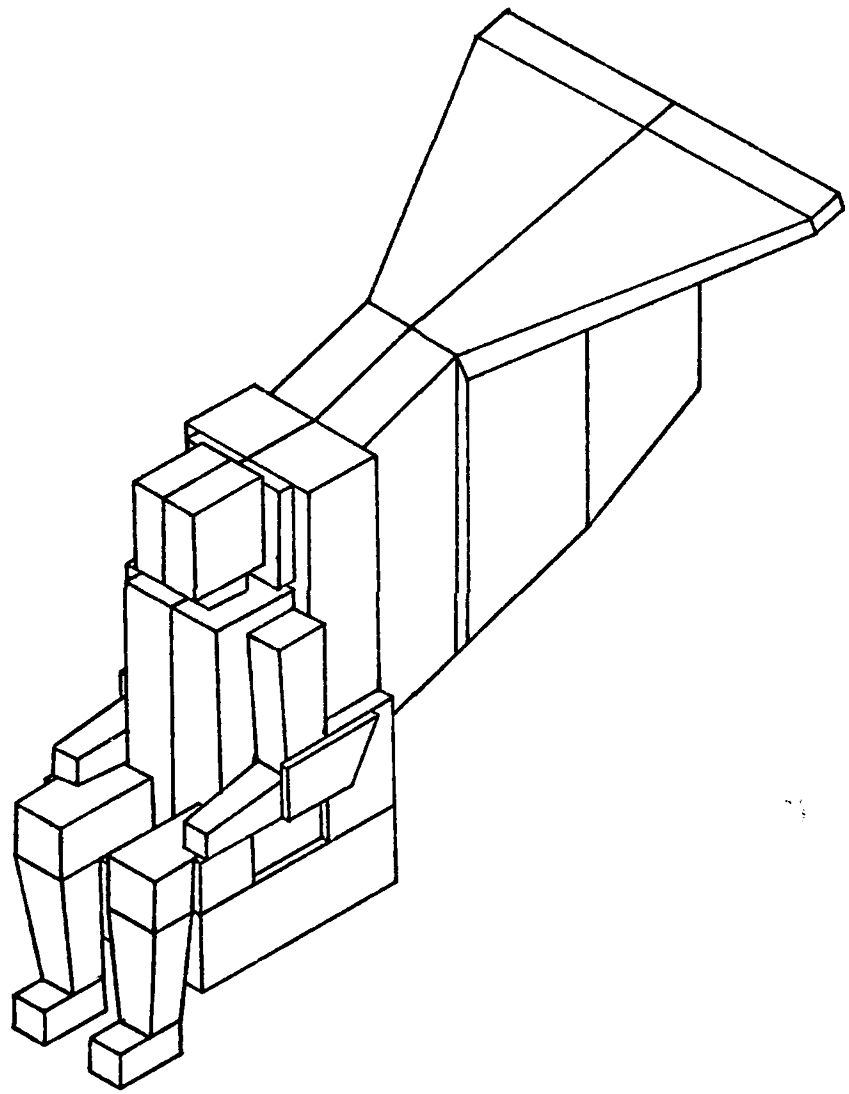
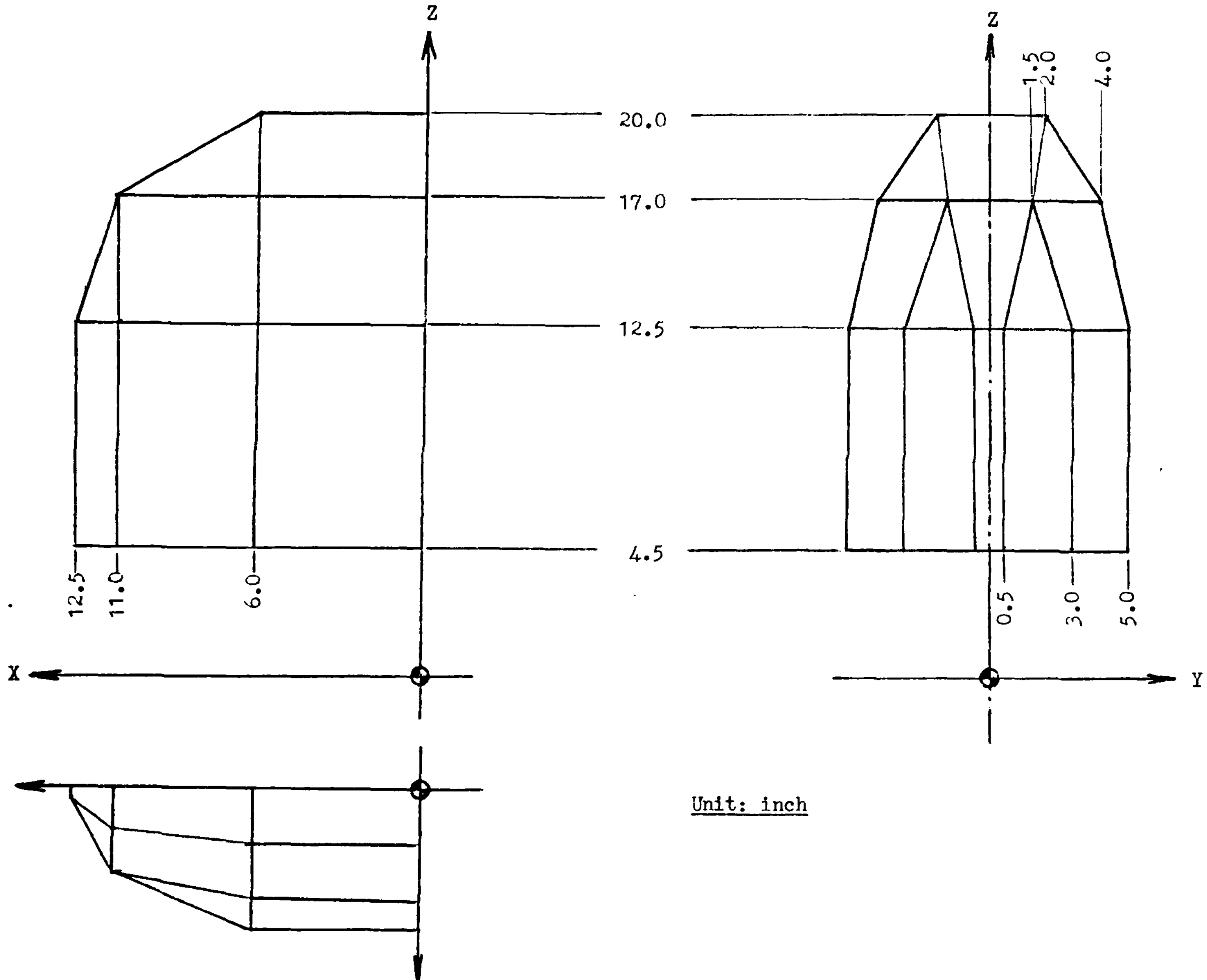


Fig. 12 Computer Model Configuration No. 7 - Perspective View



Unit: inch

Fig. 13 Computer Model Blast Shield - Model Reference Dimensions

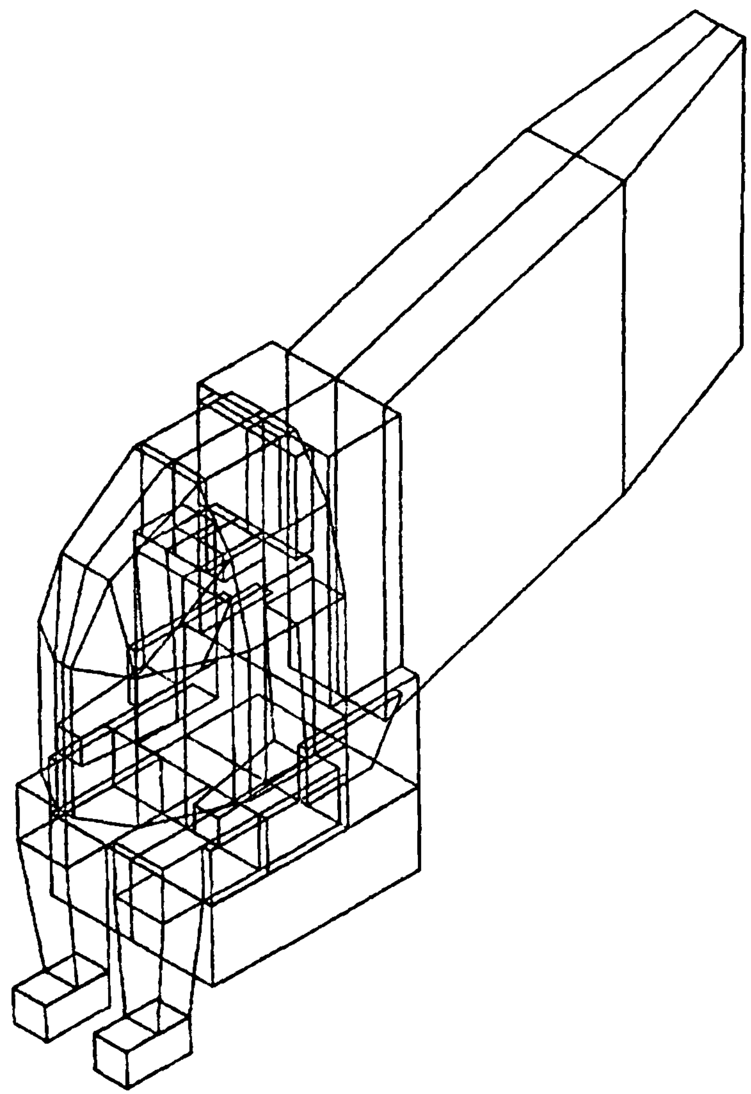


Fig. 14 Computer Model Configuration No. 3 - Picture drawn by Computer Graphics

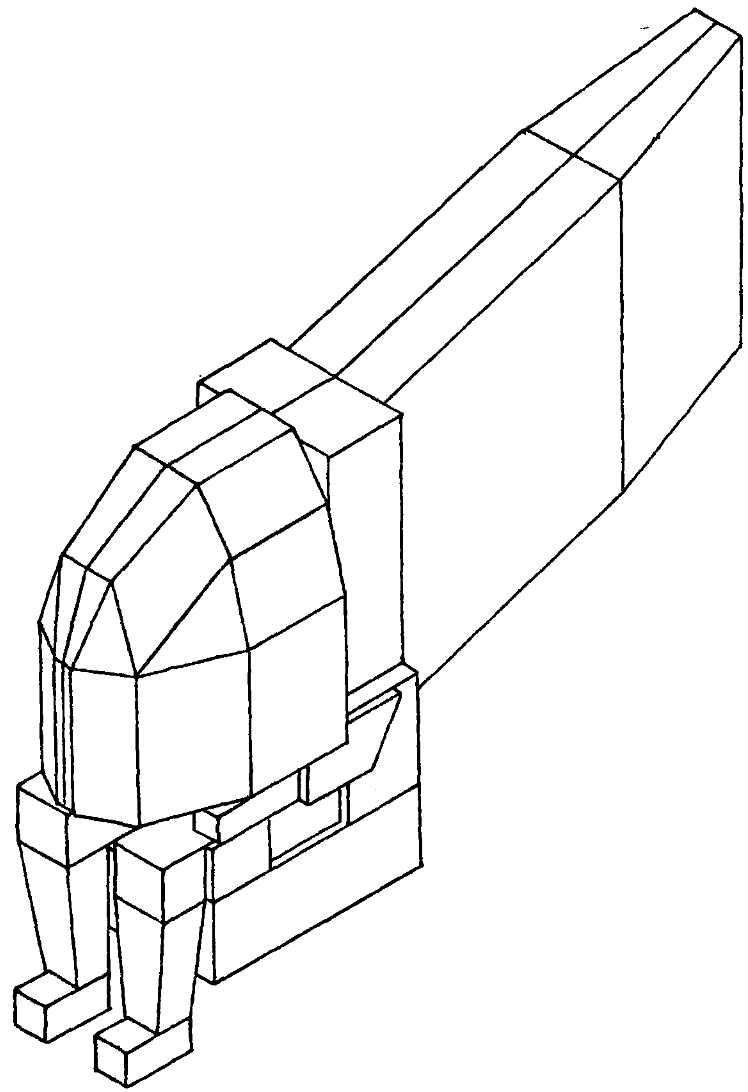


Fig. 15 Computer Model Configuration No. 3 - Perspective View

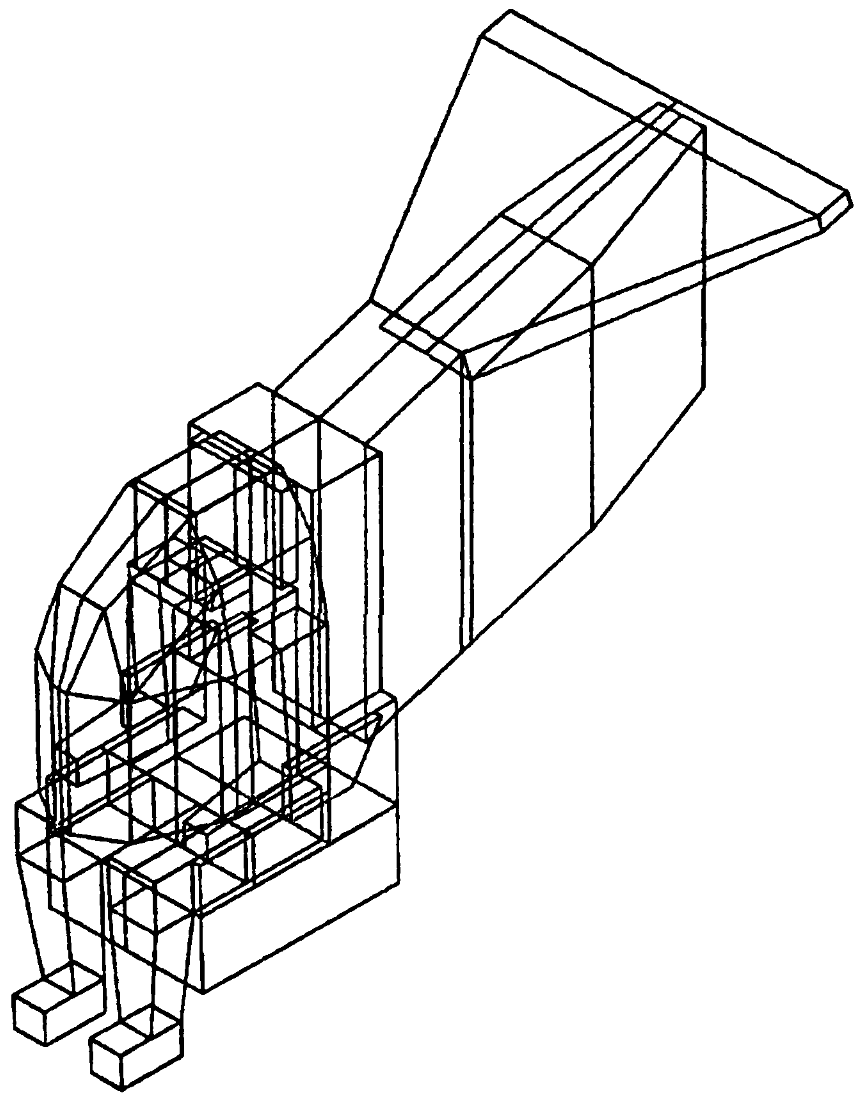


Fig. 16 Computer Model Condiguration No. 1 - Picture drawn by Computer Graphics

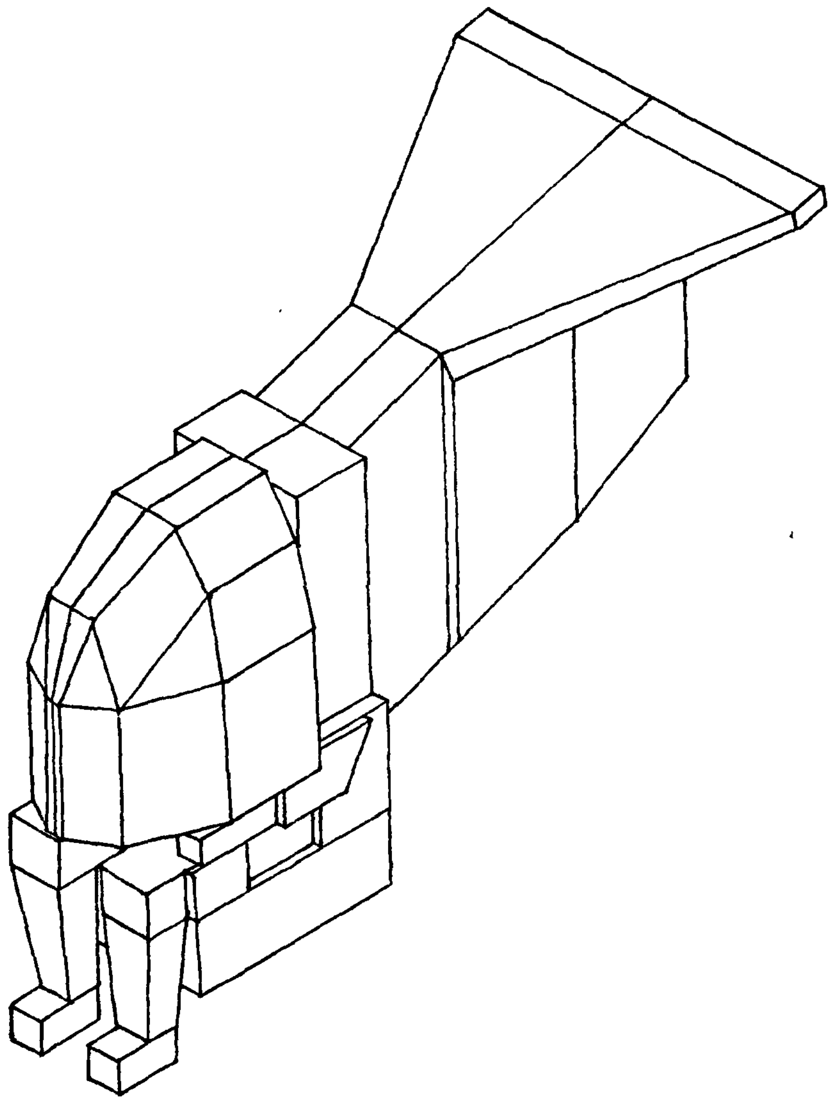


Fig. 17 Computer Model Configuration No. 1 - Perspective View

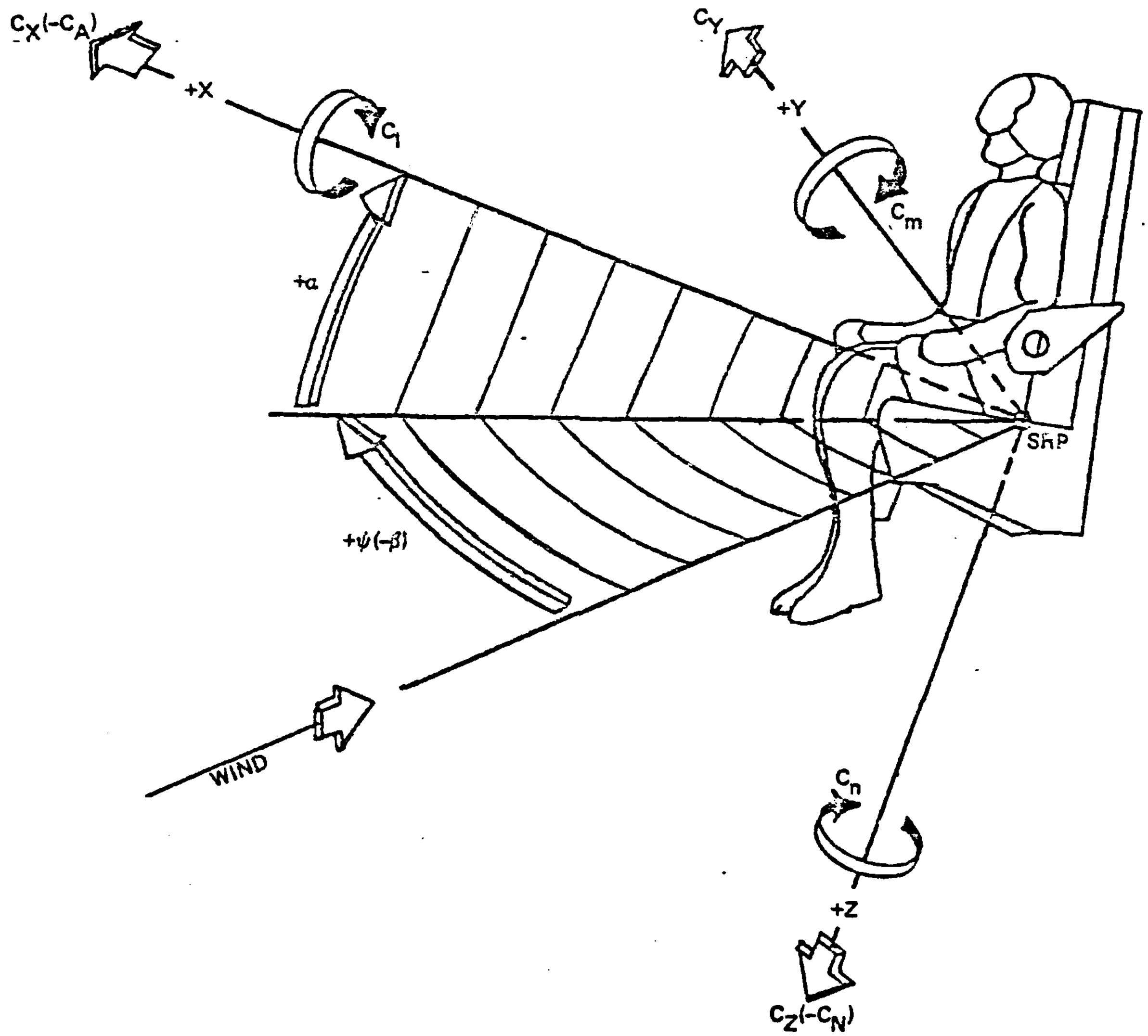


Fig. 18 Definition of Standardized Body Axis System, Positve Aerodynamic Coefficients and Angles used in Wind Tunnel Test (Fig. 22 of Reference 6)

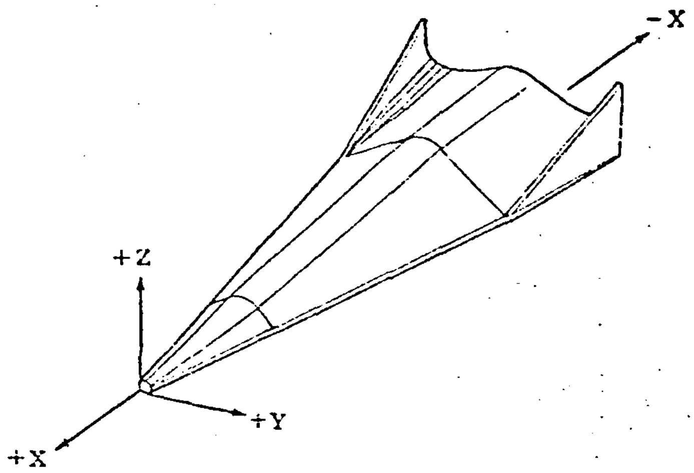


Fig. 19 Input Geometry Coordinate System used in Mark IV Computer Program (Fig. 4, p. 23, Mark IV User's Manual, Vol. I)

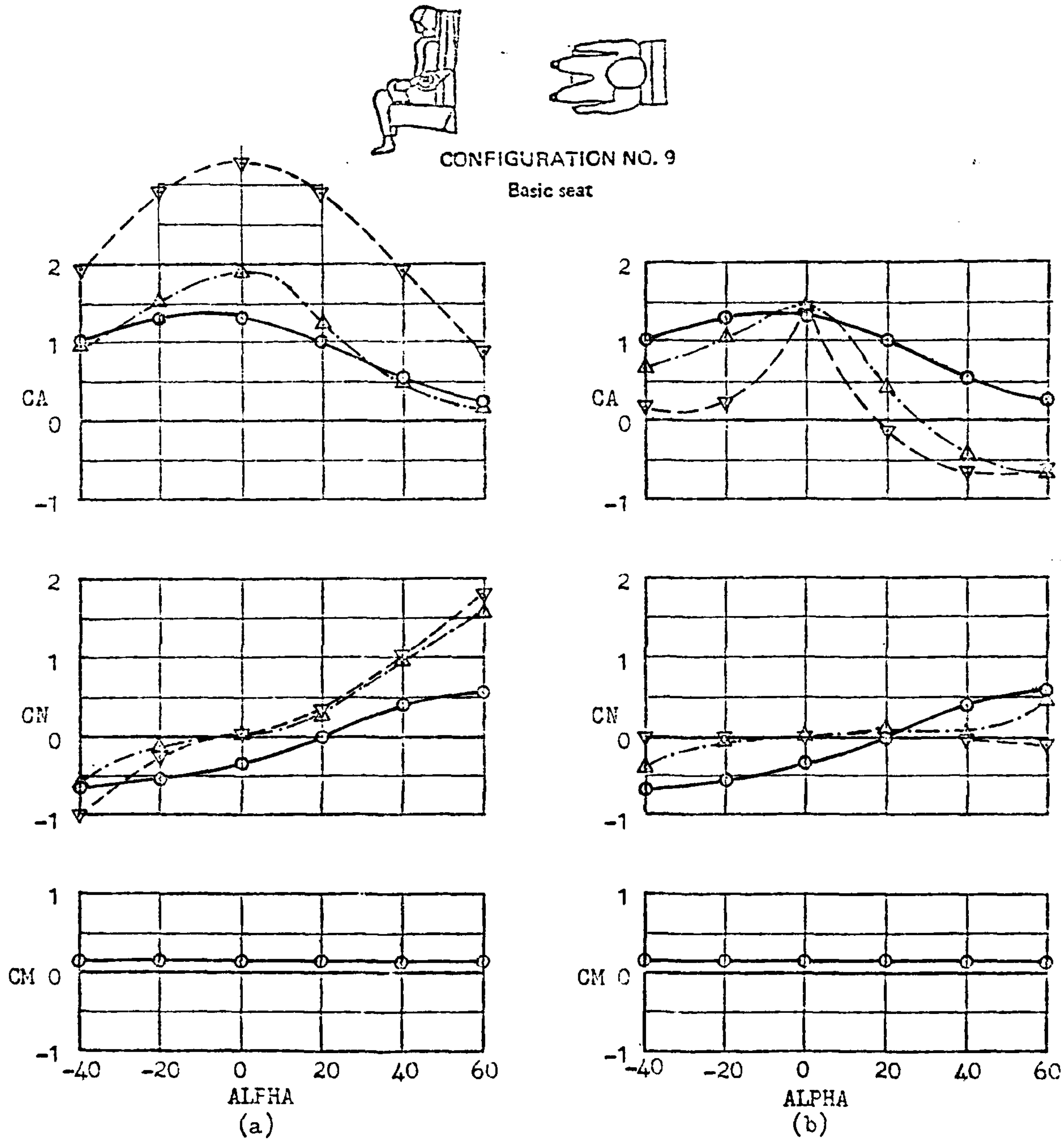


Fig. 20 Configuration No. 9 - Effect of Shielding
(a) No shielding vs. some shielding
(b) Extensive shielding vs. simple shielding

(a) ▽ No shielding
△ Some shielding
o Wind tunnel test

(b) ▽ Extensive shielding
△ Simple shielding
...o Wind tunnel test

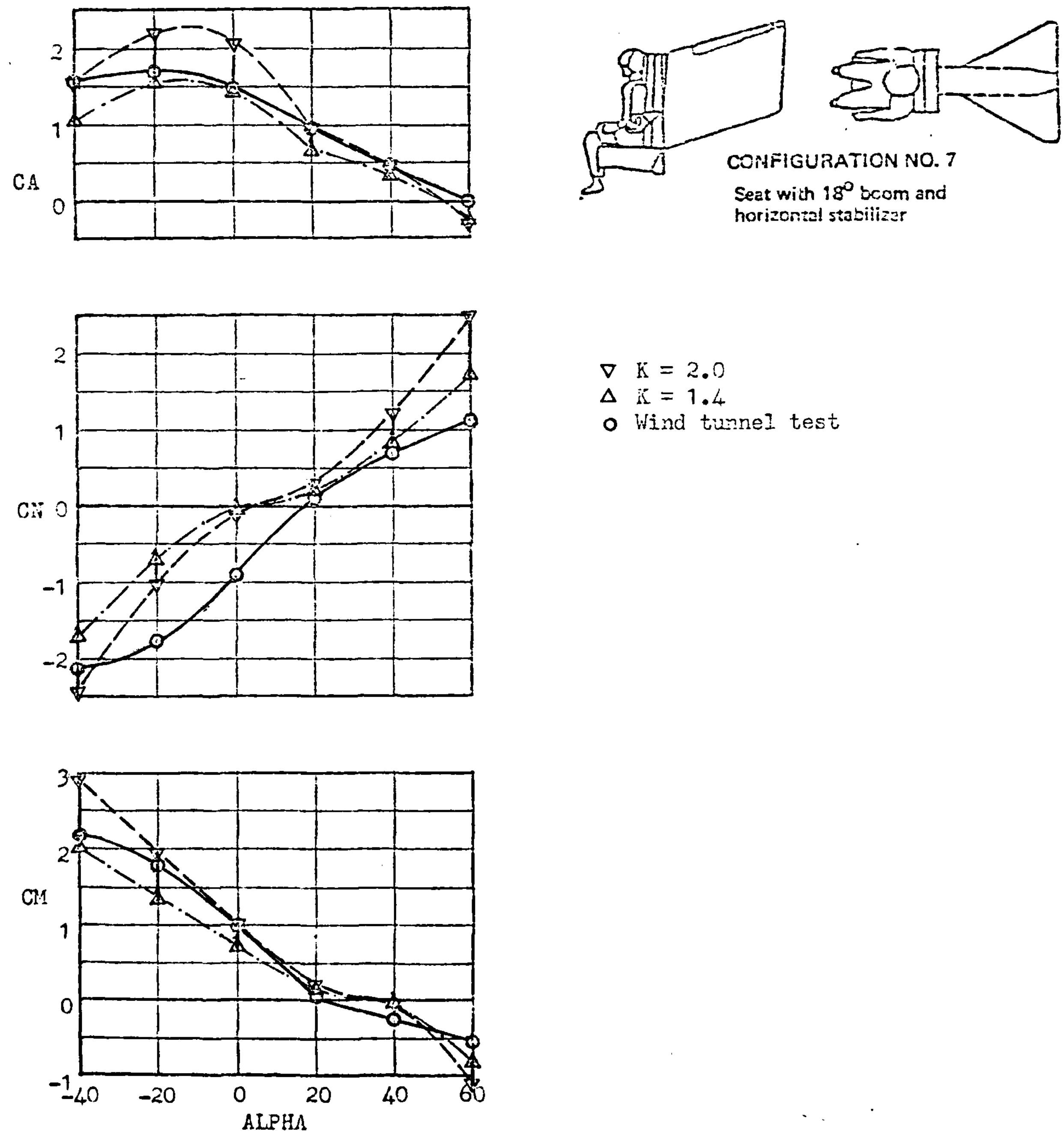


Fig. 21 Configuration No. 7 - Effect of K

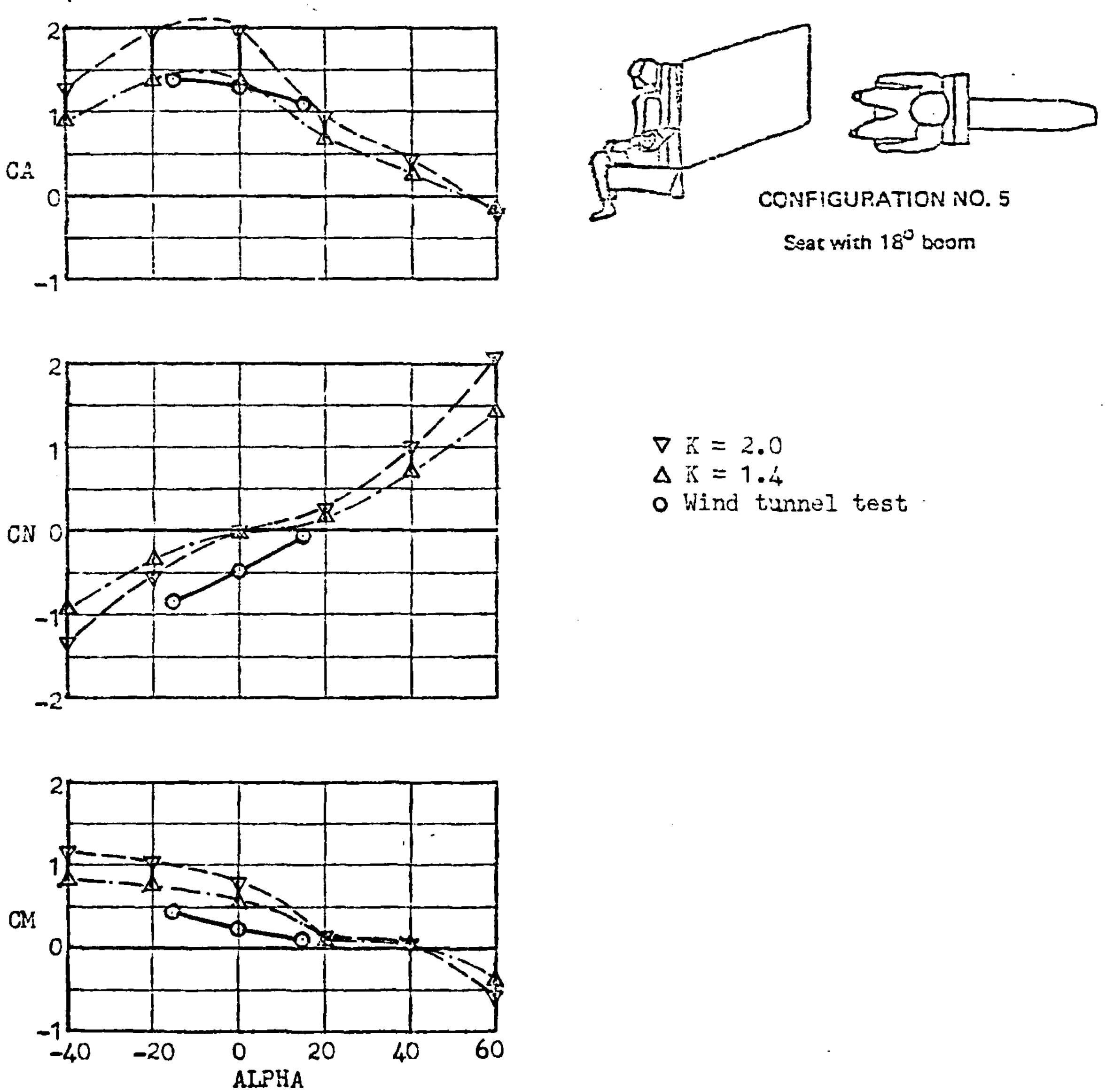
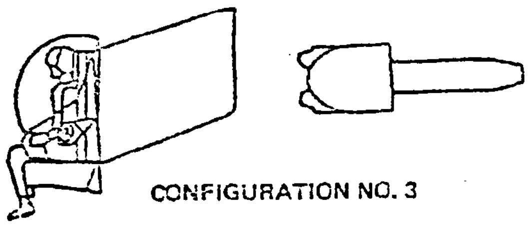


Fig. 22 Configuration No. 5 - Effect of K



CONFIGURATION NO. 3

Seat with 18° boom & blast shield

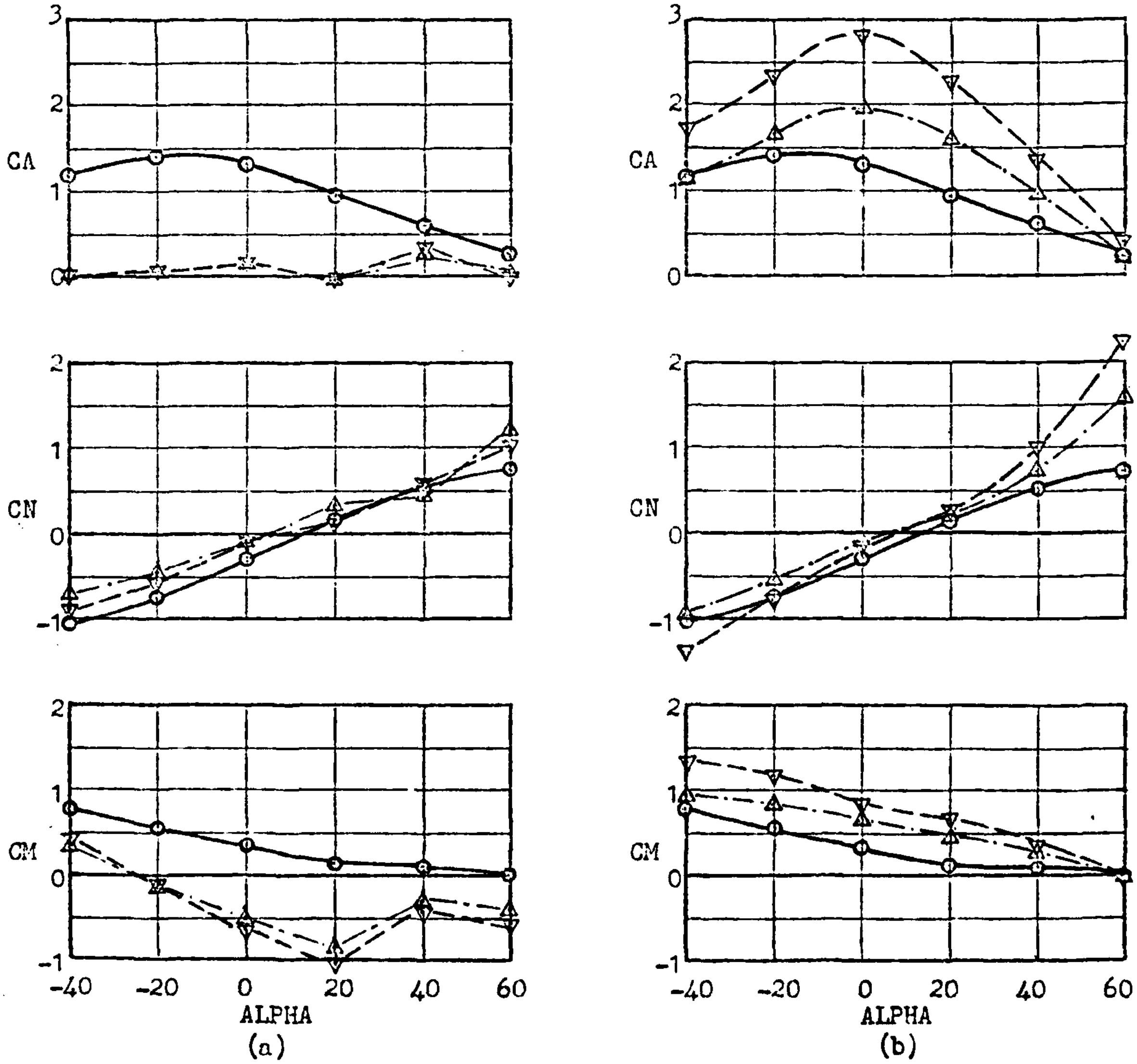


Fig. 23 Configuration No. 3 - Effect of Geometry data

(a) Configuration No. 3 (b) Configuration No. 3A

▽ K = 2.0 △ K = 1.6 o Wind tunnel test

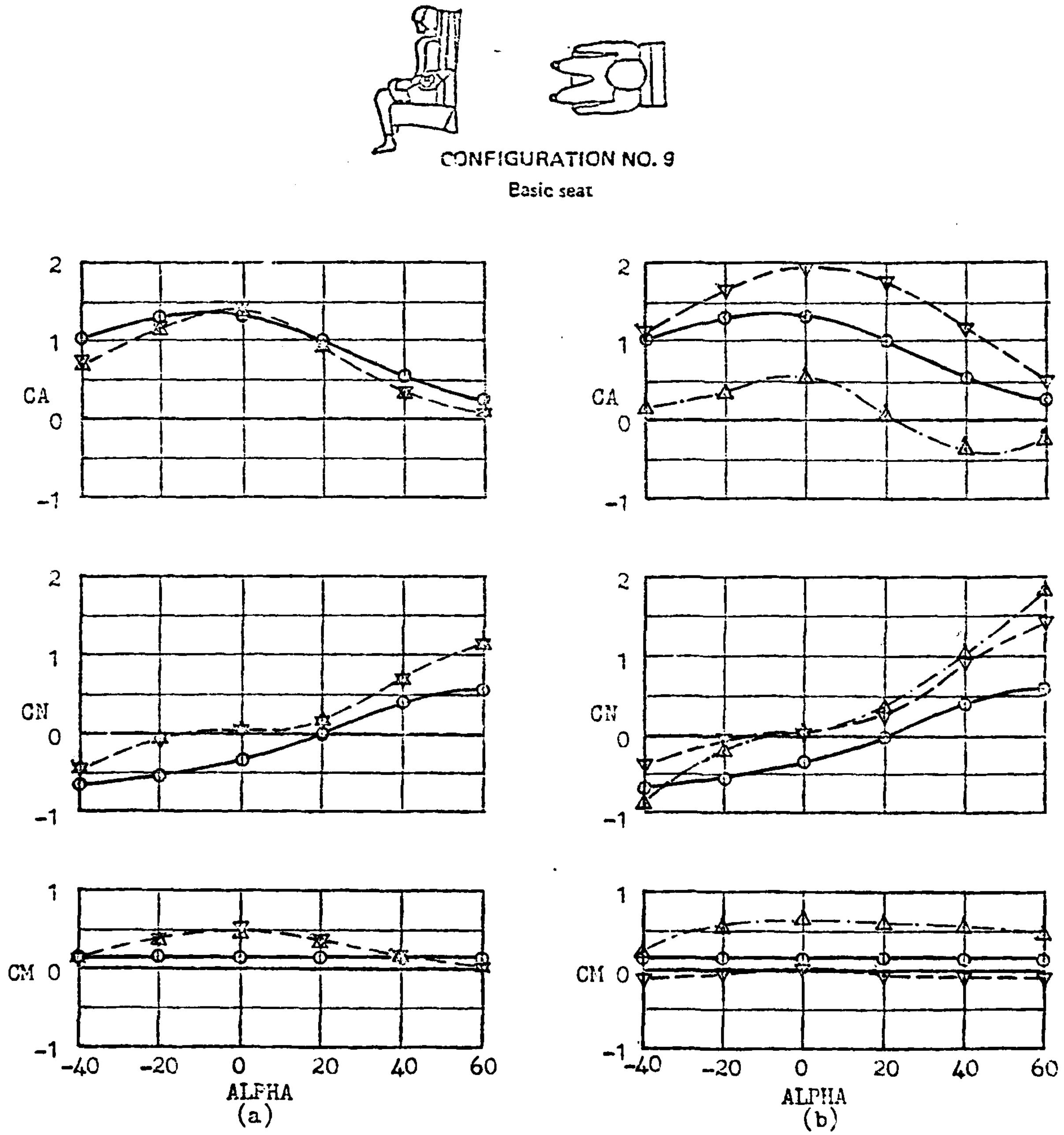
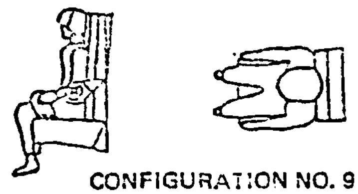


Fig. 24 Configuration No. 9 - Effect of Geometry Data
(a) Effect of deleting small panels (Configurations 9B & 9C)
(b) Effect of overlapping areas (Configuration 9X)

(a) ▽ Configuration No. 9B
△ Configuration No. 9C

(b) ▽ With shielding
△ No shielding



CONFIGURATION NO. 9

Basic seat

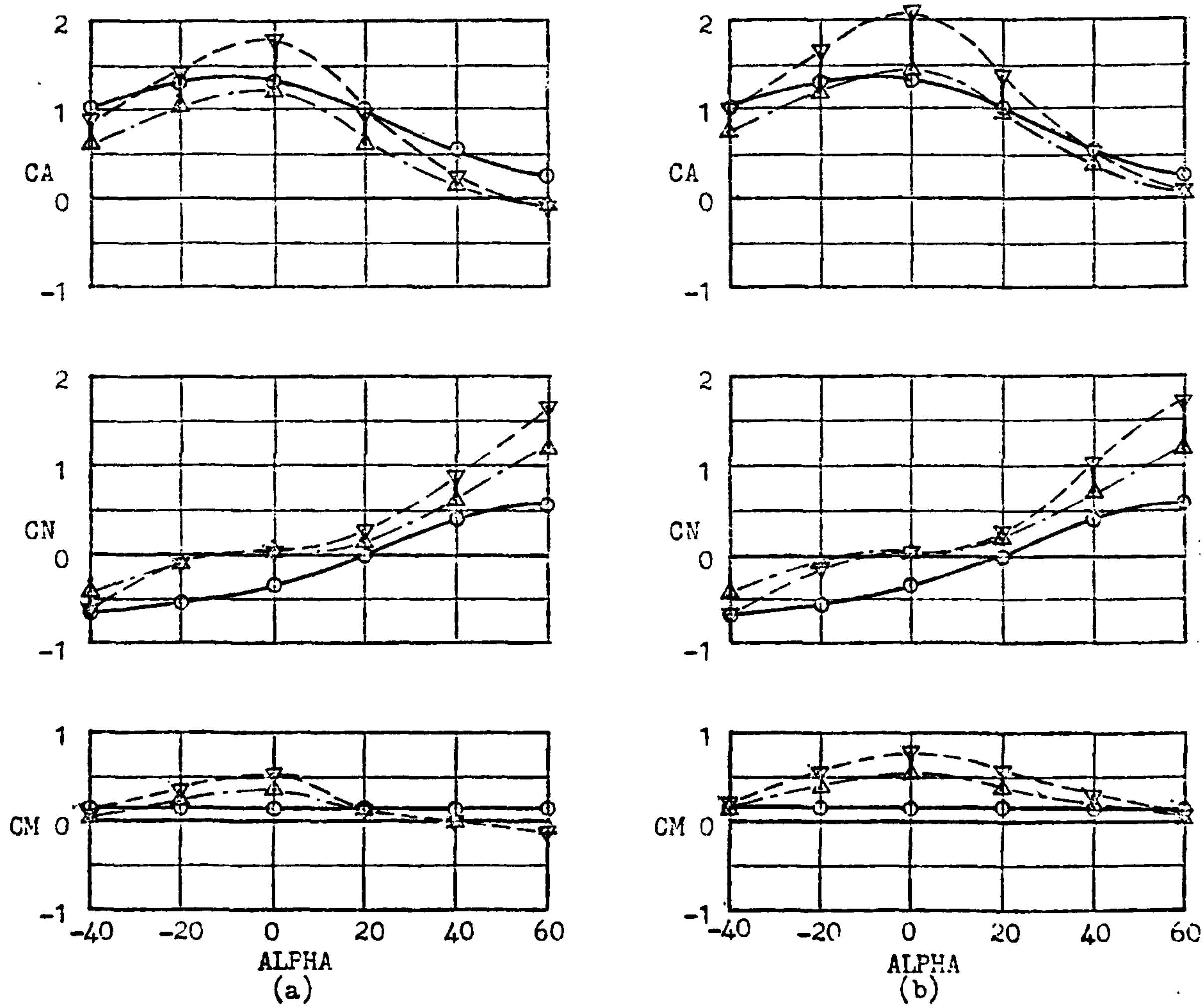


Fig. 25 Configuration No. 9 - Effect of Shielding
(a) Simple shielding (2 panels)
(b) Simple shielding (9 panels)

▽ K = 2.0   △ K = 1.4   o Wind tunnel test

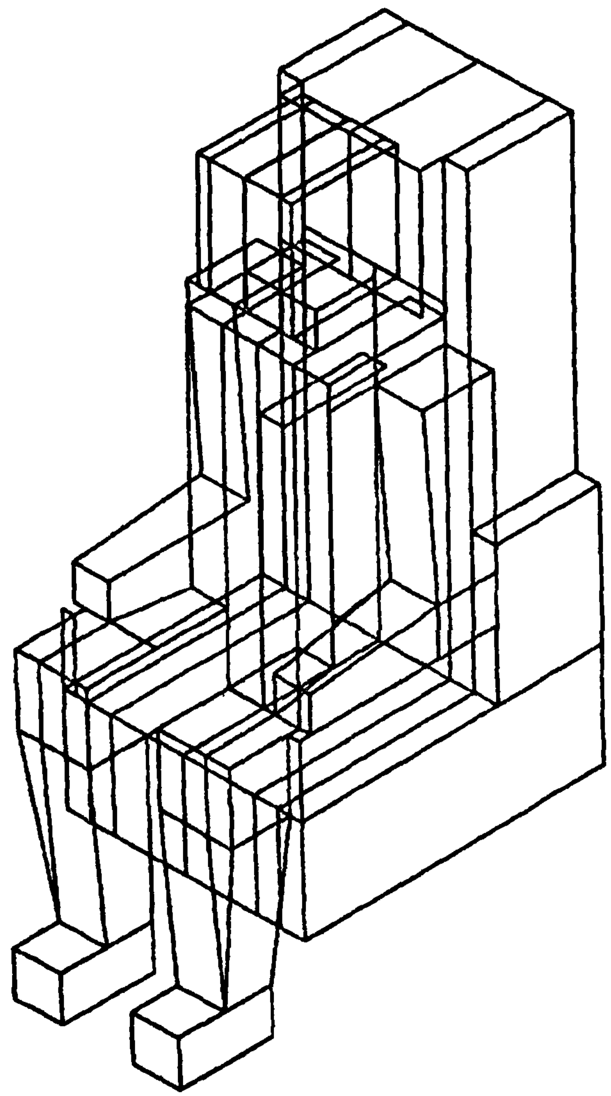


Fig. 26 Computer Model Configuration No. 9Y - Picture drawn by Computer Graphics

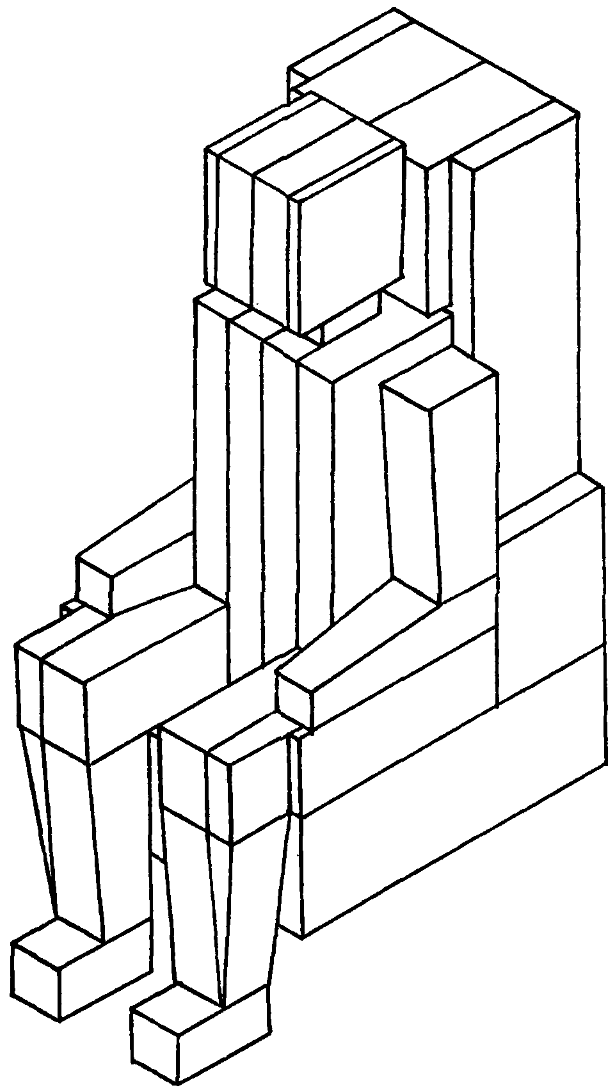
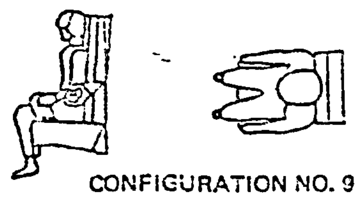


Fig. 27 Computer Model Configuration No. 9Y - Perspective View



CONFIGURATION NO. 9
Basic seat

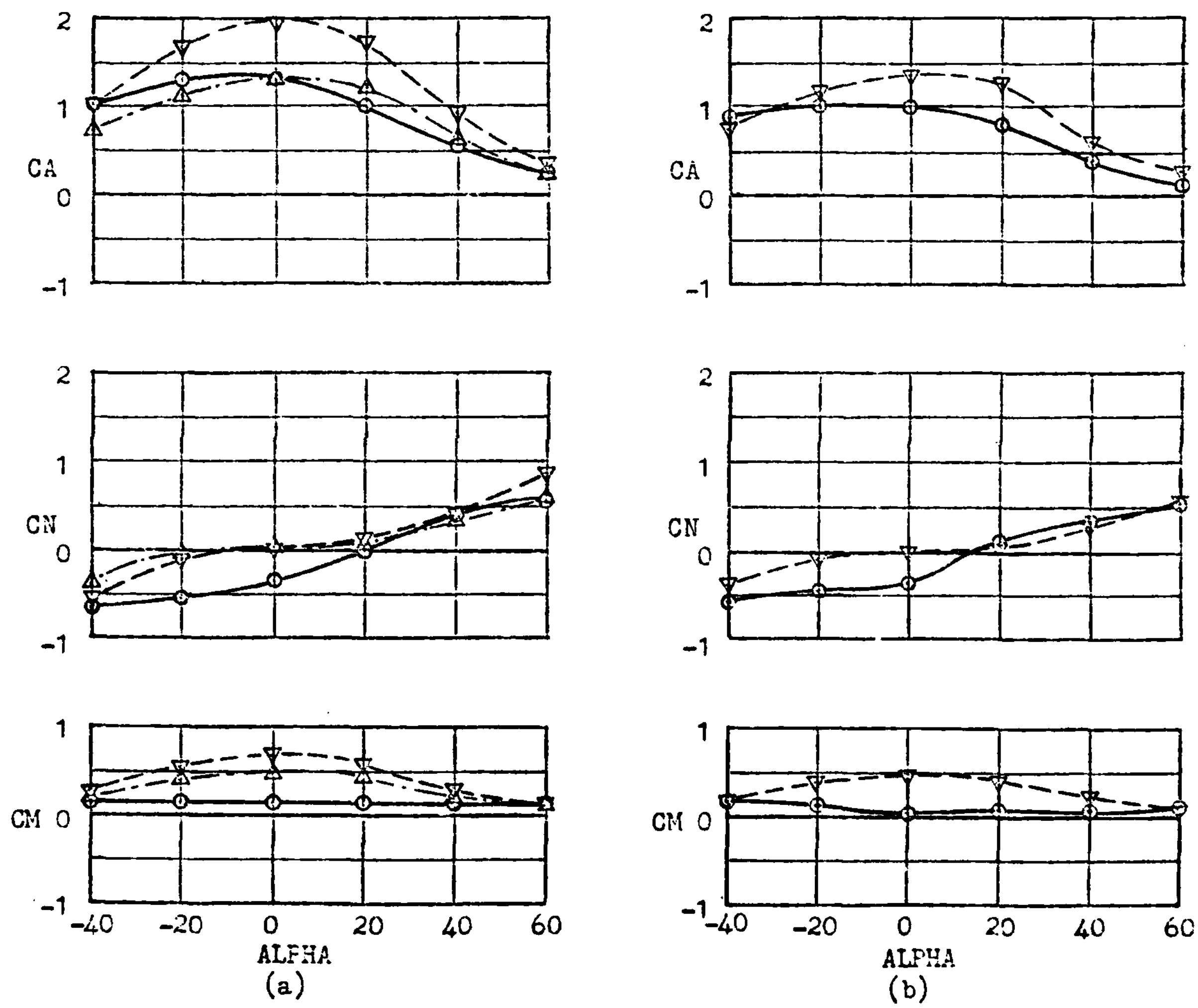
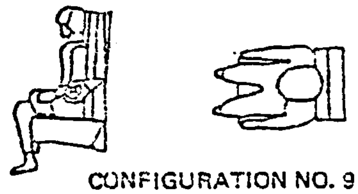


Fig. 28 Configuration No. 9Y - (a) Mach = 1.5, K = 1.4-2.0
(b) Mach = 0.9, K = 1.4

(a) ▽ K = 2.0
△ K = 1.4
○ Wind tunnel test

(b) ▽ K = 1.4
○ Wind tunnel test



CONFIGURATION NO. 9

Basic seat

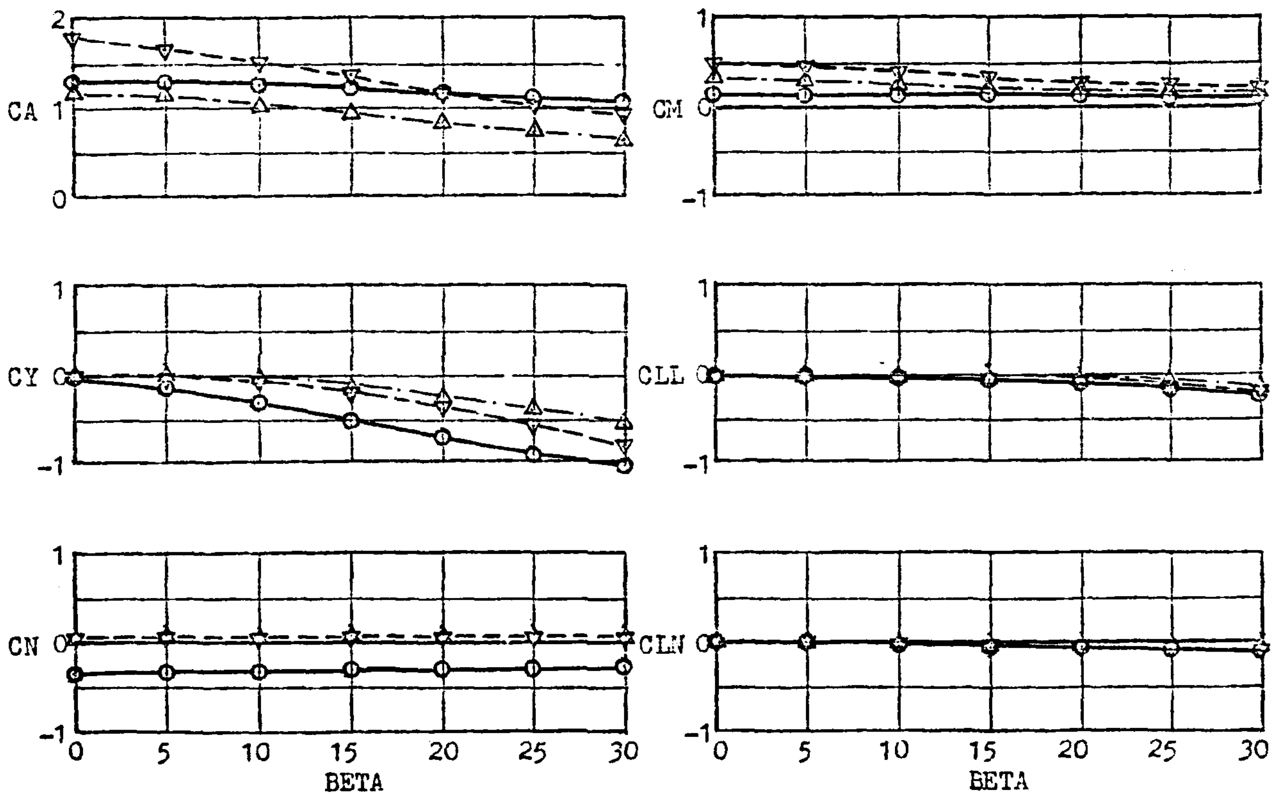
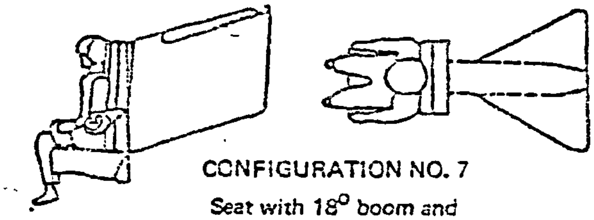


Fig. 29 Configuration No. 9A - Variable Beta (ALPHA = 0)

▽ K = 2.0 △ K = 1.4 ○ Wind tunnel test



CONFIGURATION NO. 7

Seat with 18° boom and horizontal stabilizer

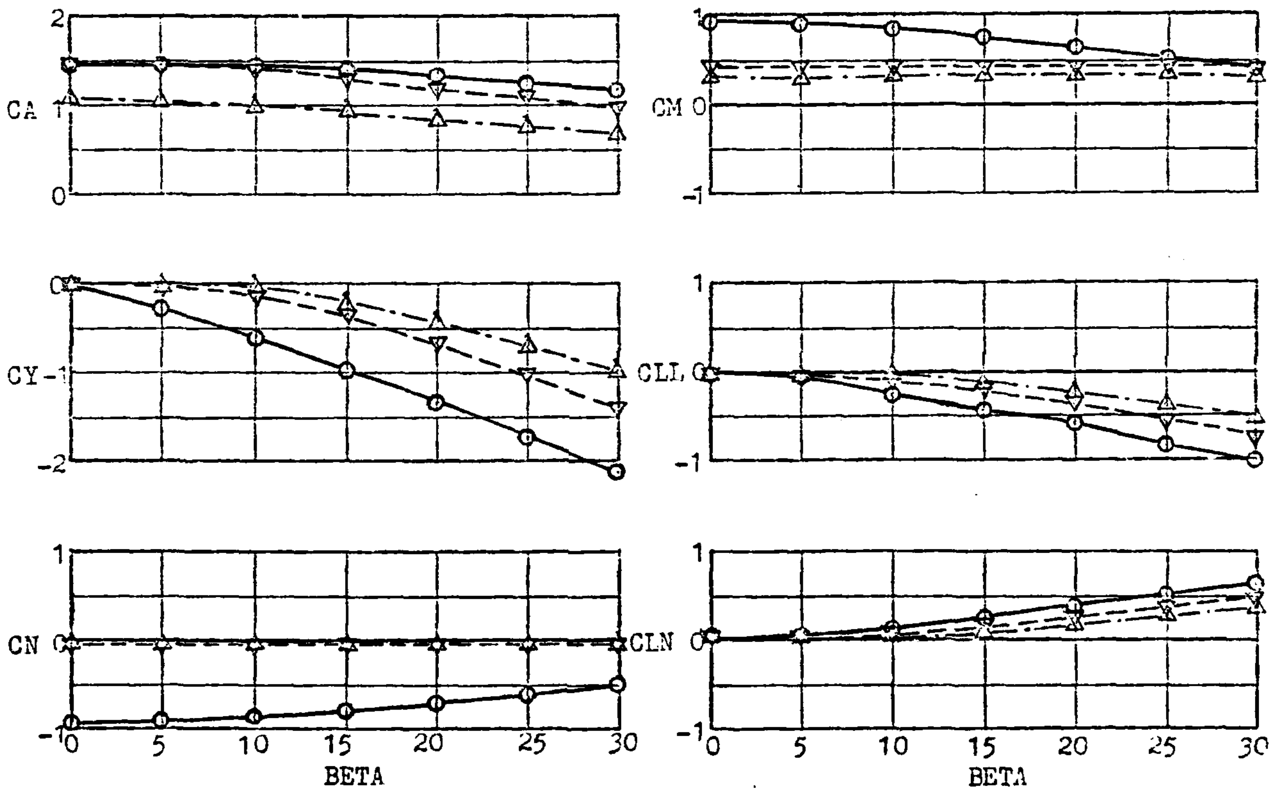
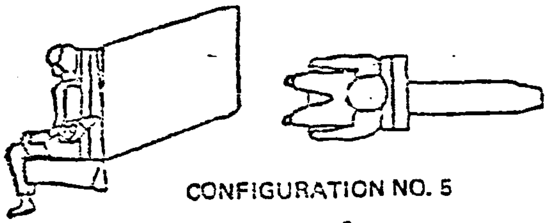


Fig. 30 Configuration No. 7 - Variable Beta (ALPHA = 0)

▽ K = 2.0   △ K = 1.4   o Wind tunnel test



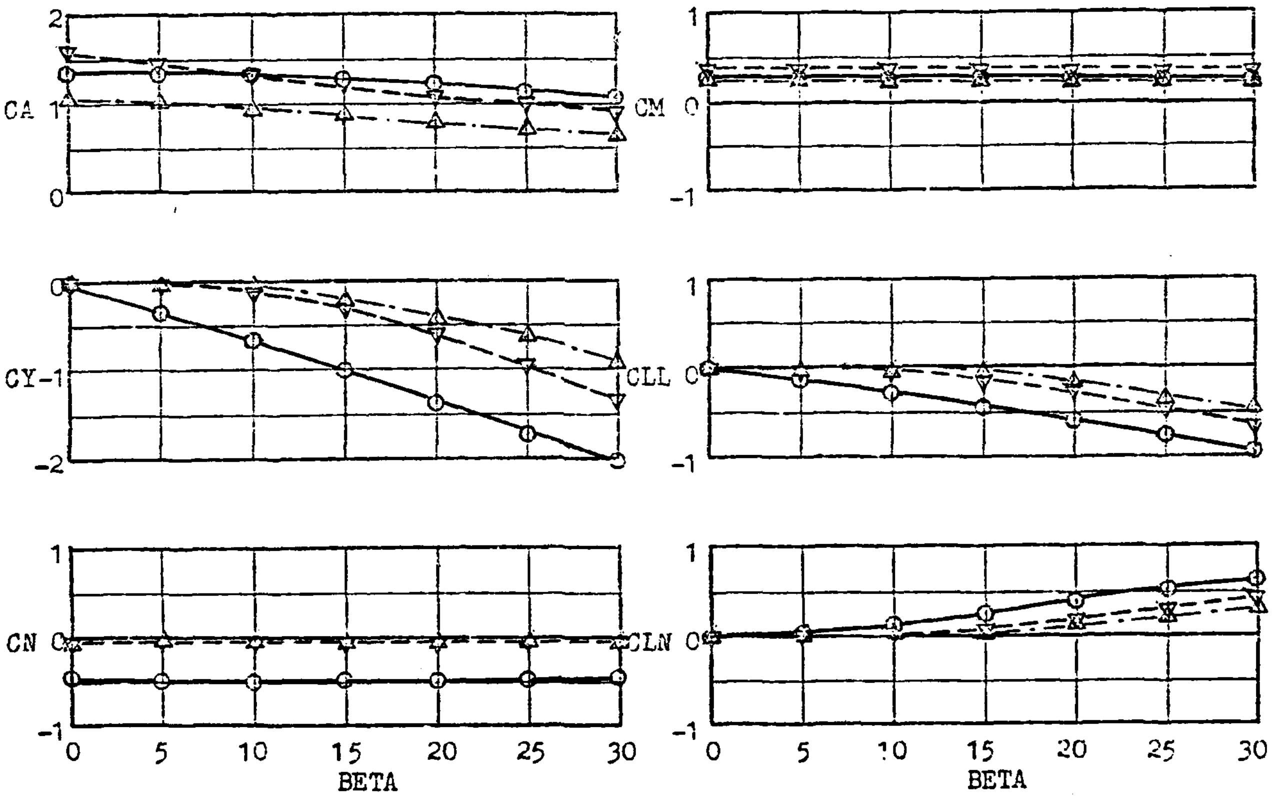


Fig. 31 Configuration No. 5 - Variable Beta (ALPHA = 0)

∇ K = 2.0   Δ K = 1.4   o Wind tunnel test

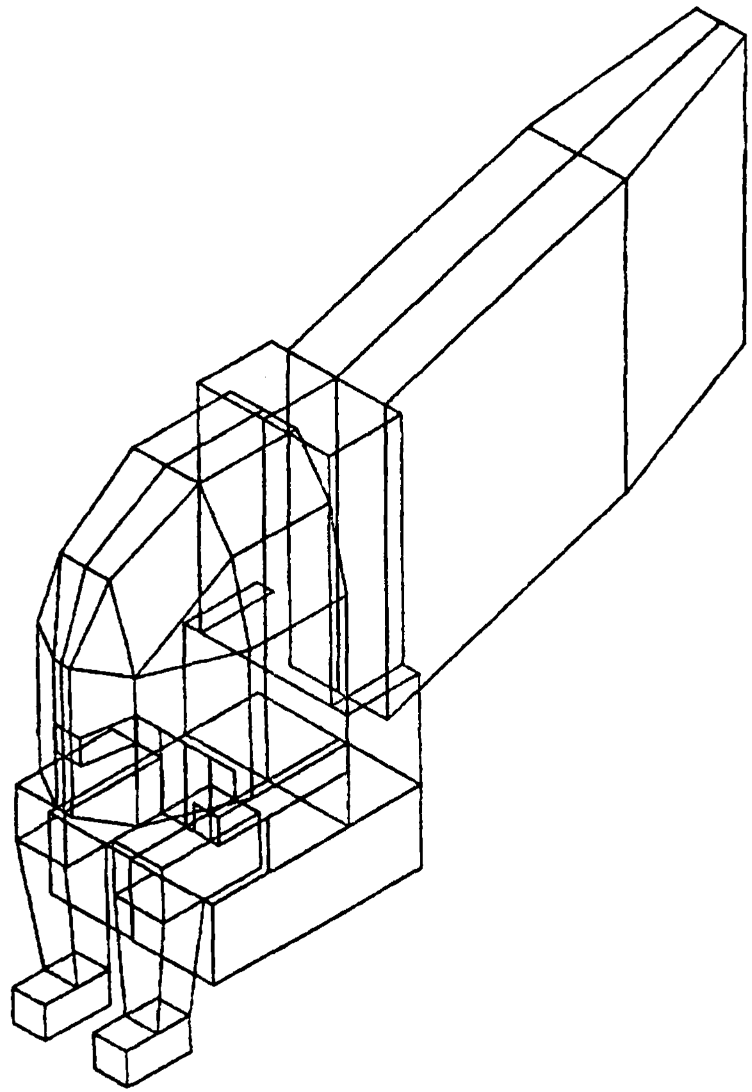
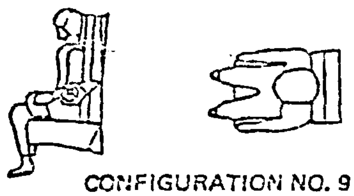


Fig. 32 Computer Model Configuration No. 3A - Picture drawn by Computer Graphics



CONFIGURATION NO. 9

Basic seat

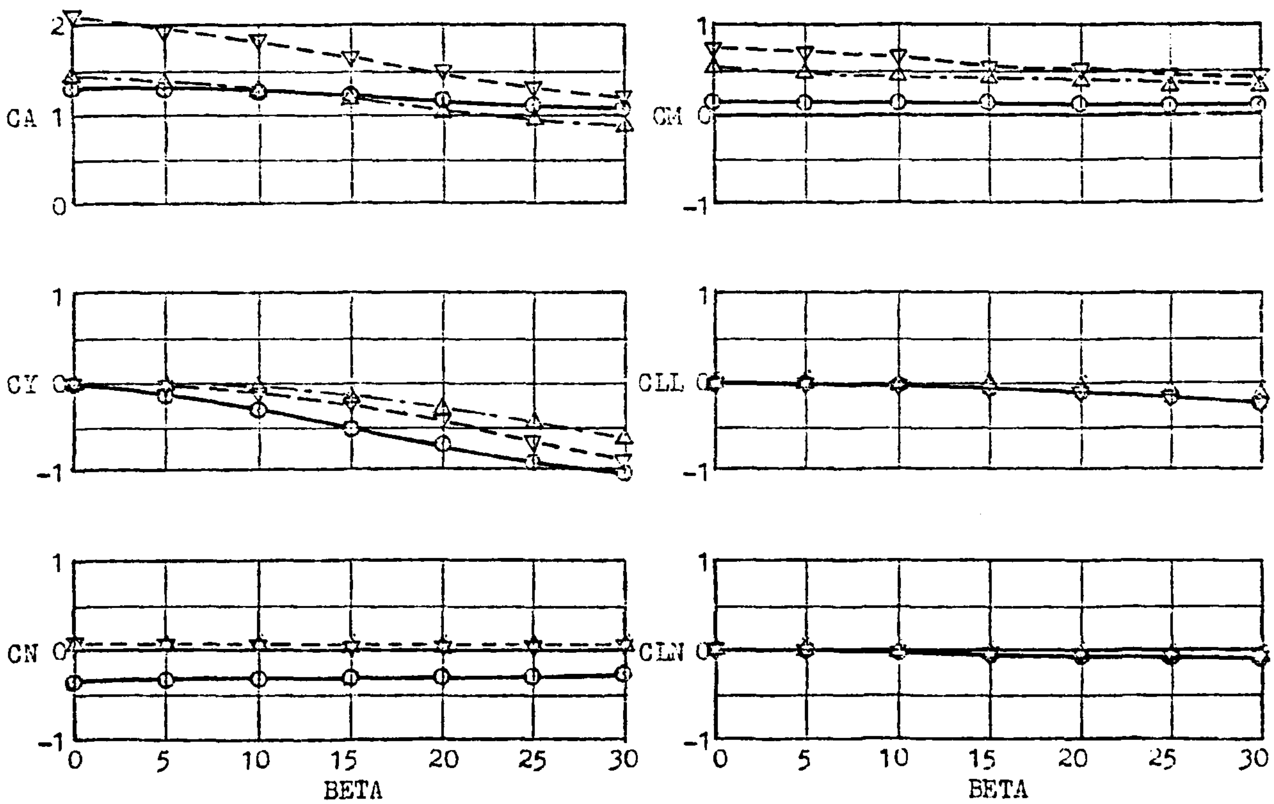
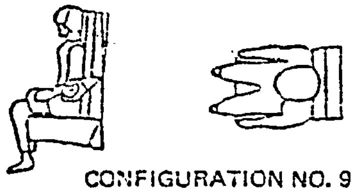


Fig. 33 Configuration No. 9 - Variable Beta (ALPHA = 0)

▽ K = 2.0 △ K = 1.4 ○ Wind tunnel test



CONFIGURATION NO. 9

Basic seat

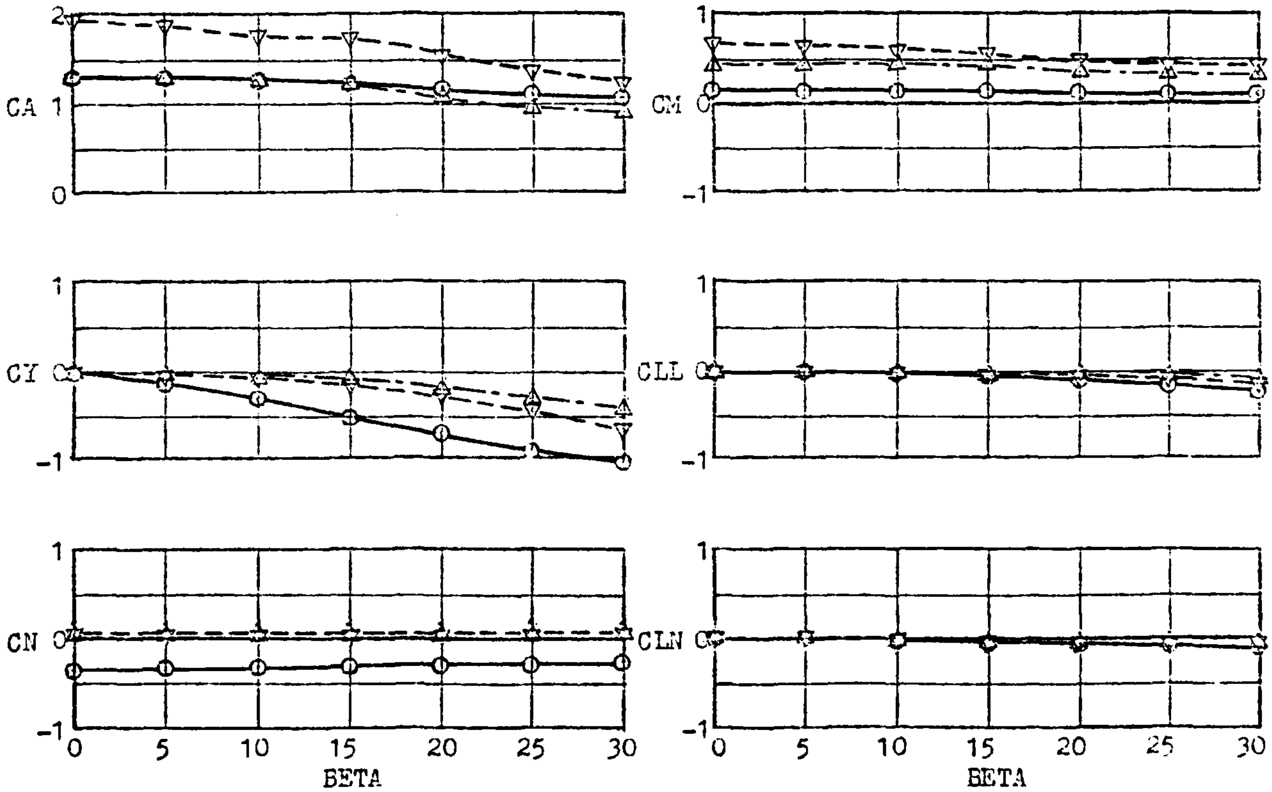


Fig. 34 Configuration No. 9Y - Variable Beta (ALPHA = 0)

▽ K = 2.0 △ K = 1.4 o Wind tunnel test

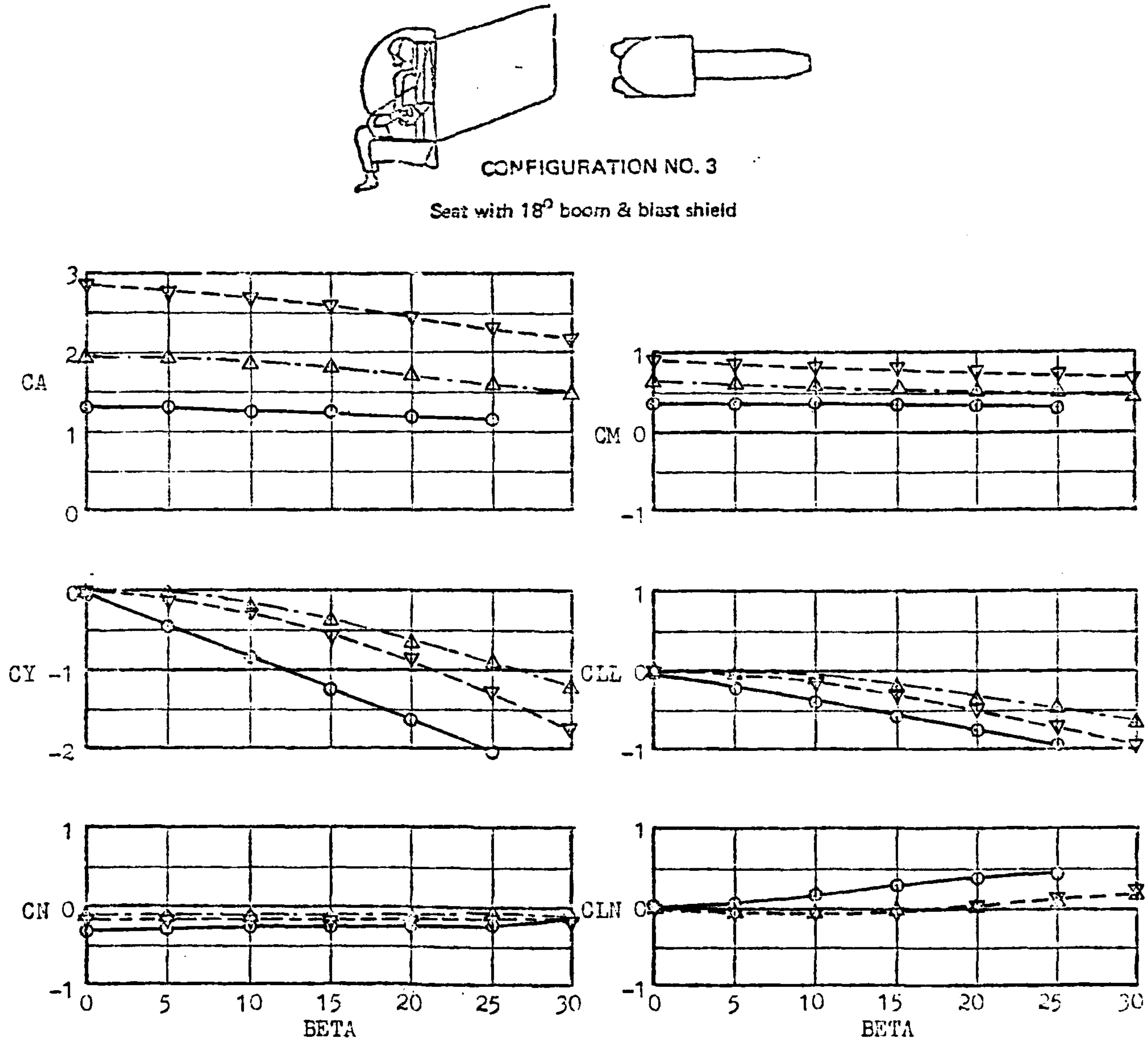


Fig. 35 Configuration No. 3A - Variable Beta (ALPHA = 0)

▽ K = 2.0 △ K = 1.4 ○ Wind tunnel test

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2. D. C. Chiang, "Computer Codes Applicable to the Determination of Ejection Seat/Man Aerodynamic Parameters," Final Report, 1979 USAF-SCEEE Summer Faculty Research Program, August 10, 1979.

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6. J. O. Bull, D. T. Ther, and R. F. Yurczyk, "Advanced Ejection Seat for High Dynamic Pressure Escape, Wind Tunnel Test Report," AFWAL-TR-80, May, 1980.